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THE IMPACTS OF FLOODING AND METHODS OF ASSESSMENT IN URBAN AREAS OF BANGLADESH

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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TO
MY BELOVED FATHER
WHO WAS MY TEACHER
BEST FRIEND AND WELL-WISHER

ABSTRACT

THE IMPACTS OF FLOODING AND METHODS OF ASSESSMENT IN URBAN AREAS OF BANGLADESH

This research is the first of its kind in Bangladesh. It focuses upon flood losses in urban sectors of the country's economy. The broad research question is whether flood impacts in urban or non-agricultural sectors are important in Bangladesh, given that it is currently an agricultural economy. The research examines the applicability of existing urban flood impact assessment methods, and develops methods suitable to Bangladesh. An important aim is to accumulate a knowledge base of flood impacts in the urban or non-agricultural sectors.

With appropriate modifications, flood loss assessment methods generated in developed countries may be applied in a developing country such as Bangladesh. However, the 'synthetic' approach of constructing standard potential flood loss data sets is not feasible. Using surveys of actual floods, the construction of reasonably high-quality 'average' data sets proves to be feasible, as floods in Bangladesh are not sparse. The construction of data sets through regressions is preferred because it is more realistic and cost-effective. The widely-used unit-loss model is found to be applicable to appraisals of urban protection schemes. However, the successful application of the model depends on the accuracy of land use and land level survey data, and detailed hydraulic and hydrological information. In Bangladesh, this form of modelling is found to be suitable for project appraisals ranging from small to intermediate scale. Some methods, however, are suitable for up to full scale appraisals.

The major achievement of the research is that flood loss potential for urban sectors has been thoroughly investigated, providing flood loss data of a significantly higher quality that are available hitherto in Bangladesh. In providing these data the research is a significant advance upon the methods recommended within the existing FPCO Guidelines for project assessment, and those used in recent FAP urban protection studies. The assessments methods developed and the standard damage data sets constructed may now be used to appraise urban protections, which will also facilitate evaluation of agricultural projects more comprehensively through incorporating non-agricultural losses that can be averted in such schemes.

The research reveals that the urban sectors of the economy are highly vulnerable to floods. Induced by rapid urbanisation, potential urban flood losses in Bangladesh are expected to be progressively more important in the future. Poverty is found to be fundamental to flood hazard vulnerability: the poorest of the poor have the most to lose in proportional (to value) terms.

A high priority can now be given to protect urban and commercial centres in Bangladesh. Given limited resources in Bangladesh, low-cost non-structural measures are also important. Local knowledge and informal flood warning systems have a positive bearing on resilience-building. Community cohesion, together with family kinships, are also important in this respect. Different types of floods (e.g. river flood, flash flood and tidal surge) are associated with differential impacts: tidal floods prove the most destructive.

Flood impacts at the macro-level are not found to be as severe as those at the micro-level. The findings suggest that floods deepen poverty and help widen the income gap between rich and poor. This problem poses further research questions regarding 'equity' and sustainable development. Project appraisal methods using conventional 'economic efficiency analysis' need to be re-calibrated in order to confront the problems relating to inequity and sustainable development, especially in the context of existing socio-economic conditions in Bangladesh.

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In spite of all help and assistance above, the responsibility of any errors that may remain is mine.

THE IMPACTS OF FLOODING AND METHODS OF ASSESSMENT IN URBAN AREAS OF BANGLADESH

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LIST OF ABBREVIATIONS

BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCA	Benefit-cost analysis
BIDS	Bangladesh Institute of Development Studies
BWDB	Bangladesh Water Development Board
CMI	Census Manufacturing of Industries
CPP	Compartmentalisation Pilot Project (FAP-20)
DGHS	Directorate General of Health Services, GOB
EIA	Environmental Impact Assessment
EIP	Early Implementation Project
ESTDAM	A computer package developed by FHRC for estimating total damage
FAP	Flood Action Plan (for Bangladesh)
FFW	Food for Work Programme
FCD/I	Flood control, drainage and/or irrigation projects
FHRC	Flood Hazard Research Centre, Middlesex University, UK
FPCO	Flood Plan Coordination Organisation
GDP	Gross Domestic Product
GNP	Gross National Product
GOB	Government of the People's Republic of Bangladesh
IDNDR	International Decade for Natural Disaster Reduction
I-O	Input-output analysis or Table
ISPAN	Irrigation Support Project for Asia and the Near East
JICA	Japan International Cooperation Agency
MLF	Ministry of Livestock and Fisheries (Bangladesh)
MPO	Master Plan Organisation
MRR	Ministry of Relief and Rehabilitation (Bangladesh)
MOA	Ministry of Agriculture (Bangladesh)
MSL	Mean Sea Level
NGO	Non-governmental Organisation
PWD	Public Works Department
R & H	Roads and Highways Department
RL	Reduced level
VA	Value added, which is gross output less costs of inputs and services
WHO	World Health Organisation
WFP	World Food Programme

BANGLADESHI LOCAL TERMINOLOGY

Allah	God
Aman	A wet season rice crop; Transplanted Aman, transplanted in approximately July and Broadcast Aman sown in approximately April.
Aus	A wet season rice crop, sown in pre-monsoon period, approximately April.
Bazar	Bengali name of a market place, which usually sits specific days a week
Beel	Natural depressions which are rich in flood-plain fisheries
Boro	A dry season rice crop, sown in approximately November.
Char	A sand bar which is formed within a river or estuary
District	An administrative unit under a Division.
Division	An administrative unit comprising several Districts.
Dua	Flood walls around plinths in low-cost houses
Hat	A temporary village market, usually held once or twice a week
Hartal	Bengali name of work strike.
Kharif	Wet season (mid-April to mid-October)
Kutcha	For roads, made of earth; for house, made of earth, bamboos and thatched.
Pourasava	Bengali name of Municipality.
Pucca	Houses or roads, made of brick, cement and rod.
Rabi	Dry season (mid-October to mid-April)
Taka (TK)	National currency (£ = TK 65 in January 1997)
Thana	Administrative unit under a District, formerly called Upazila; main unit of local government.
Union	or Union Parishad, the local administrative unit in between Mouzas and Thanas
Upazila	A former administrative unit under a District, now called Thana.
Zila	Bengali name of a District.

CHAPTER 1: INTRODUCTION AND AIMS OF THE STUDY

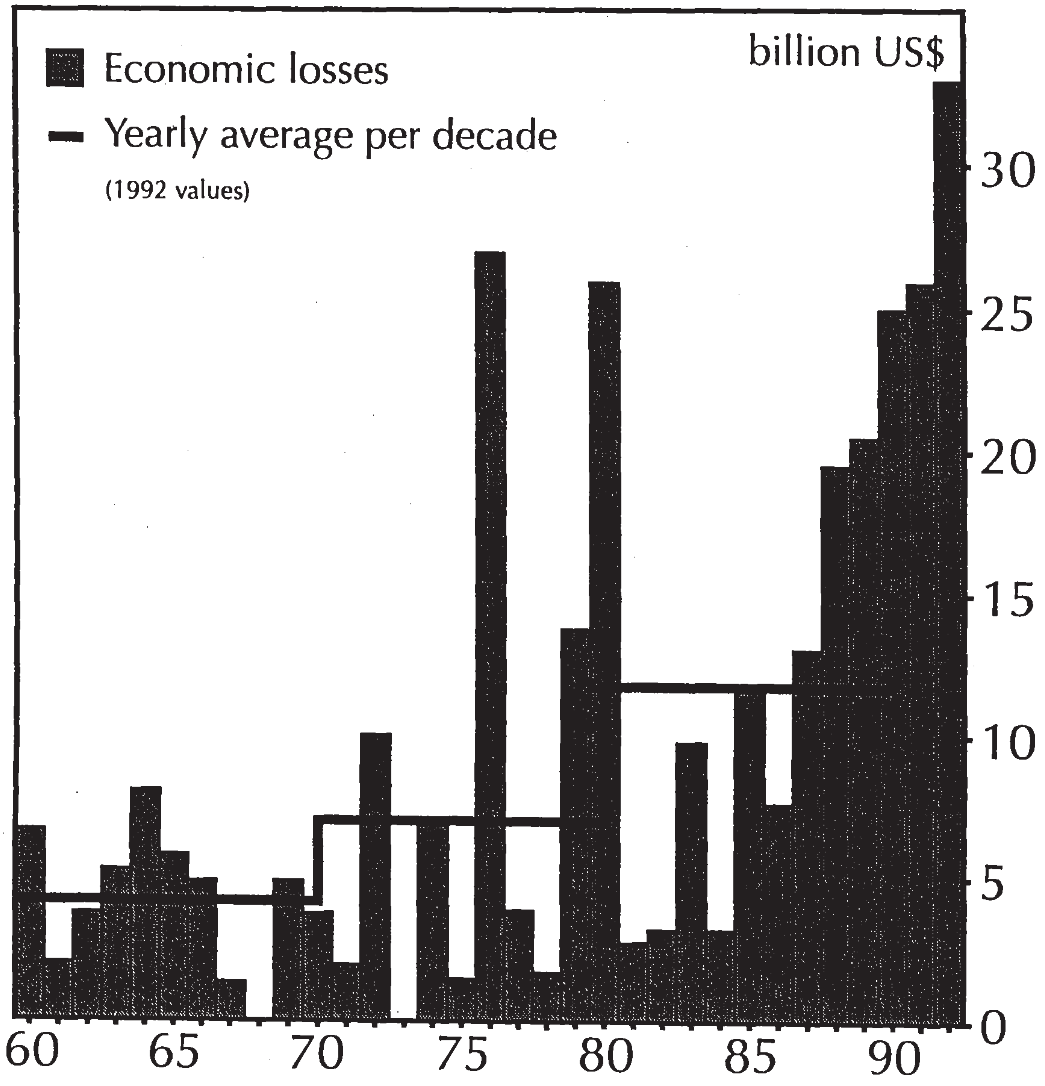
1.1 Background to the Research

The research seeks to reveal, conceptualise and categorise impacts caused by flooding in urban areas of Bangladesh. Besides accumulating a sound knowledge base of the impacts, the study aims to test the applicability of existing impact assessment methods and principles, and to develop suitable methods for Bangladesh using an appropriate developing country perspective.

Natural hazards such as floods, cyclones, droughts and earthquakes are increasingly the source of immense misery to humans, although the frequency of such events as a whole may not be increasing. The World Disasters Report (1994) argues that there were 158 'recorded' major natural disasters in 1993, while the annual estimate over the last 25 years (1968-92) is an average of 191 such events. An analysis of the annual data reveals that there is little evidence of the frequency of the natural hazards increasing. However, there has been a marked rising trend of economic losses produced by major natural disasters at the global scale (Figure 1.1).

Besides sharp increases in economic losses, there has been a steady rise in the number of people affected over time. For example, in the last five years, the number of people affected by major disasters across the world has risen to approximately 250 million per annum, compared to a 25-year average of 115 million (World Disasters Report 1994; Walker 1994). People now appear to be more vulnerable to disasters than in the past. The reason lies with human and socio-economic processes. People become vulnerable by being forced to live in a close proximity to hazards. People are more vulnerable because some live in the ever-increasing poverty while others live amid an increasing stock of wealth and prosperity. People are now more vulnerable because they live in an increasingly dense and unhealthy environment, the conditions of which are more susceptible to hazards than in the past. People are vulnerable because they enjoy a false sense of security in protective structures and some are unable to perceive potential risks. Others are helpless having no alternative but to live with risks. While many factors are responsible, a fundamental cause which provokes disaster proneness is human encroachment into hazard prone areas, worsened by increasing risks created by rapid urbanisation.

Figure: 1.1
Economic losses produced by great natural disasters



(Munich Reinsurance Company)

The situation of developing and poor societies is distressing. So far as the disaster-related casualties are concerned, about 95 per cent of global human losses occur in poorer nations, which constitute two-thirds of the total world population (Burton et al 1978). Although absolute economic losses are expected to be much greater in richer societies in view of their much larger share of wealth, the relative losses (to values) to the community are invariably much worse in the less developed societies. Among natural hazards, floods have profound damage dimensions, accounting for, about 40 per cent of the world's natural disasters (Burton et al 1993).

Floods are important sources of disasters in Bangladesh. Bangladesh is located in a region which is extremely vulnerable to floods, perhaps more than any other countries of the South Asian region. To the north of the country is located the world's largest mountains - the Himalayas, and to the south, the Bay of Bengal with one of the longest coastlines in the world (Figures 1.2 and 1.3). About 80 per cent of the country comprises the combined delta of three international rivers, the Ganges, the Brahmaputra and the Meghna with a total catchment of 1.8 million km^2 (Rogers et al 1989). There are as many as 700 tributaries of these rivers. The combined mean annual discharge of these rivers is next to that of Amazon (Thompson and Penning-Rowsell 1991a). Characterised by a generally flat topography and one of the highest annual rainfalls (120-145 cm) in the world, about 50 per cent of the country's area is below 12.5 metres above the sea level (Master Plan Organisation 1986). Floods occur throughout the country almost every year. An account of affected areas during the last four decades shows that on average about one fifth of the country is inundated annually (Table 1.1). A total of 23 major floods (inundating between 20 and 62 per cent of the country's land area) occurred in the past four decades (See Table 8.15 in Chapter 8).

The geographical location of the delta adds its own complications to Bangladesh's flood problem. India is everywhere upstream of Bangladesh (Figure 1.3). About 92 per cent of the total catchment (1.8 M km^2) of the three international rivers are located outside of Bangladesh; and mostly in India. With all the major rivers originating in India, Bangladesh tends to suffer from upstream externalities. India is in a position to control water (in terms of timing and quantity) before it enters Bangladesh. With this are the natural factors that magnify the problem. The act of the global warming, causing rising sea-levels (Asaduzzaman 1993; Ahmad et al 1996) and the melting of snow in the Himalayas watershed has a potential bearing on the future extent of the flood problem (A fuller implications of global warming for the analysis of flood protection in Bangladesh is discussed in Chapter 9: Conclusions).

Figure: 1.2
Flood affected areas in Bangladesh

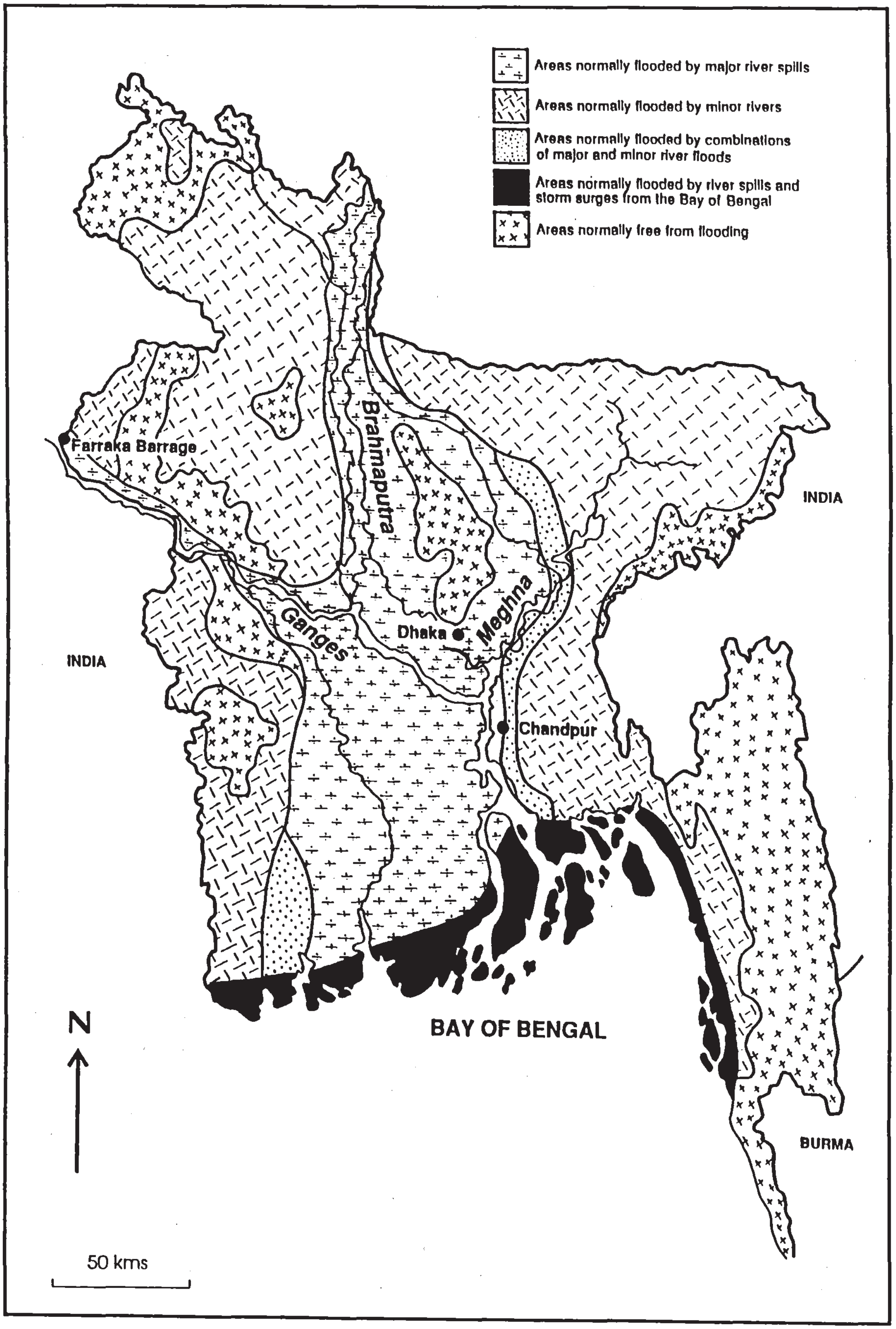


Figure: 1.3
Bangladesh and neighbouring flood source regions

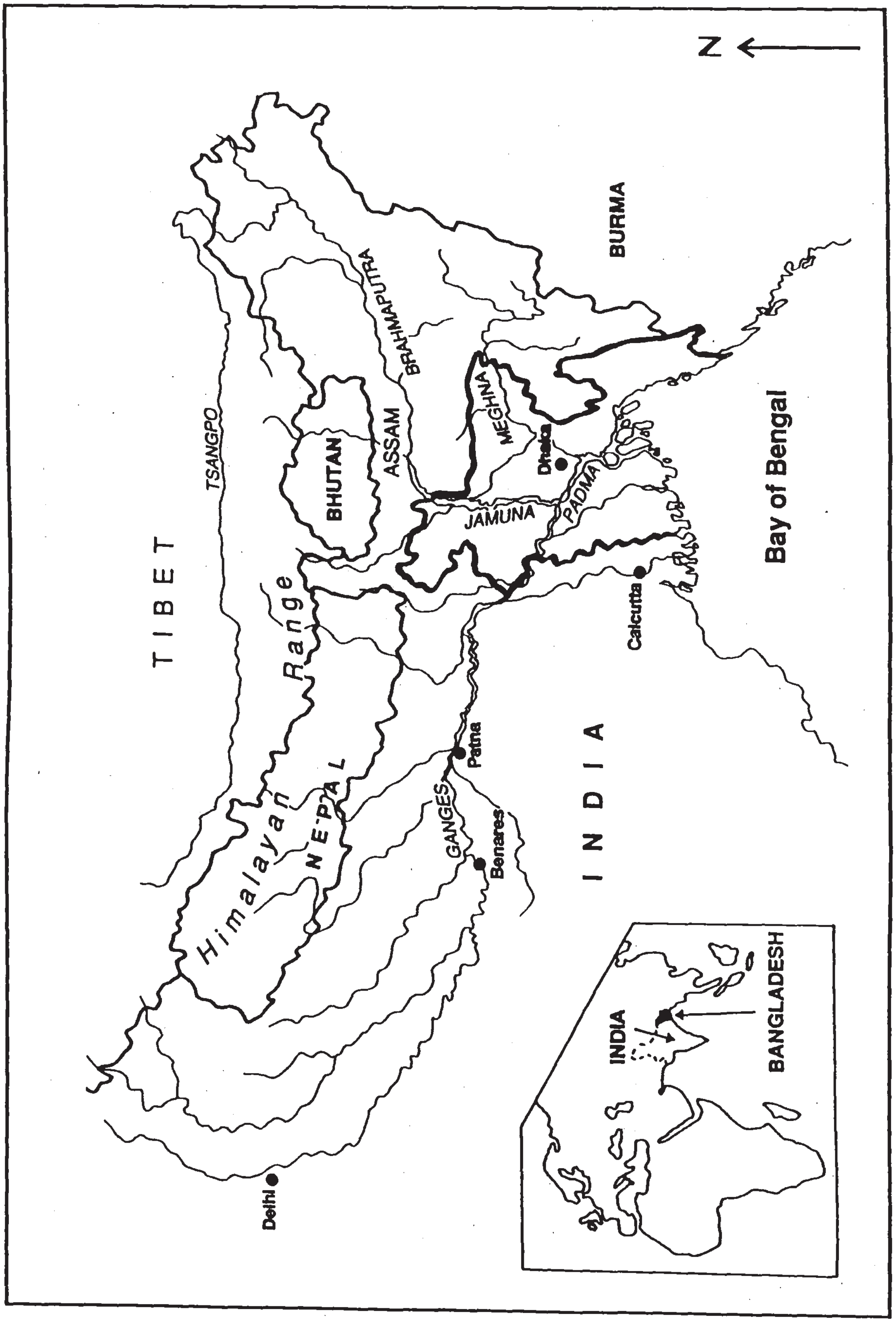


Table 1.1: Flood affected areas in Bangladesh during 1954-93

Period	Average area affected annually (Km^2)	% of area affected annually	No of major floods
1954-63	37185	25.8	7
1964-73	32697	22.7	8
1974-83	19099	13.3	3
1984-93	26034	18.1	5
Total	28070	19.5	23

Note :

Major floods are defined as those which inundated more than 20% of the total area of Bangladesh (See Table 8.15 in Chapter 8).

Source: BBS (1993a); Miah (1988b); Bangladesh Water Development Board.

Four types of floods are commonly encountered in Bangladesh. Flash floods, characterised by high discharge velocities and rapid rises and recessions, occur in eastern and northern hilly regions. Despite its short duration, this type of flood can be very destructive at local levels. Floods caused by high-intensity rainfalls in the monsoon season generate 'normal' seasonal floods. This typical flood can often be adjusted (e.g. through changes in cropping patterns), and is seldom harmful to agriculture or other sectors of the economy. In fact, annual normal floods are often beneficial to cropping through increasing fertility by alluvial deposits in the soil. They also extend irrigation water to summer crops and soil moisture to winter crops. River floods are caused by spilling of water over the banks of major rivers and their tributaries due to heavy rains and other externalities in the upstream areas. This type of flood is often catastrophic especially when the three major rivers rise simultaneously. The fourth type of flood is the dangerous cyclone-induced tidal surge that occurs in the coastal areas consisting of large estuaries and low-lying islands. The surges accompanied by tropical cyclones are commonly encountered during pre- and post-monsoon periods.

1.2 Pertinent Issues and Rationale for the Study

The well known American hazard response paradigm (Burton et al 1978), which has provided stimulus to contemporary flood hazard research, suggests that natural hazards, including floods, are the product of interactions between nature and society. In this context, it has been a grave concern that urban populations in the world, especially in the developing societies, are increasing rapidly often in an unplanned way. During 1980-92 the urban population increased by about 50 per cent in developing regions, compared with only 10 per cent in the developed nations (World Bank 1994). In Asia, for example, rapid economic growth in the next two decades is expected to induce a doubling of the number of 'megacities' to 17, exacerbating existing social and environmental problems[1].

The uncontrolled expansion of urban areas with their vast populations and their properties has led to greater exposure to floods and other natural hazards. It is increasingly recognised that large cities have now 'enormous potential for disaster creation' (Parker and Mitchell 1995b). As in other parts of the world, many of the urban areas in Bangladesh are becoming

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[1] This is according to the recent Conference on Managing Asia's Cities in Manila (Financial Times 26 October, 1996). The Conference defines a megacity as having a population of more than 10 million while the United Nations defines megacities as having a population of more than 8 million.

increasingly vulnerable to disasters. For example, Dhaka, the capital city, is approaching a megacity (defined by the United Nations as a city with a population of 8 million or more), arguably displaying 'hazard-producing characteristics' of most megacities. As in many other megacities in Asia, Dhaka is least equipped to cope with the present population and urbanisation. The growths in population and urbanisation are gradually outstripping the carrying capacity of their local and regional ecosystems. With its population of more than 6 million, the city has been expanding into the low lying areas on its periphery. With a urban population growth of 1.5% in 1970, the growth rate of Dhaka is projected to be about 18% by 2010 (Nicholls 1995). During the 1988 flood, two-thirds of the city remained under water for more than three weeks.

The present level of urbanisation (24%) in Bangladesh, remains quite low, compared to an average low-income country, let alone the middle and high-income economies. This is evident from Table 1.2, which presents comparative statistics on urbanisation in selected countries. Because the estimates are based on different national definitions of urbanisation, cross-country comparisons can be somewhat misleading; but the data presented are indicative. The Table reveals that in 1992, the level of urbanisation in the low-income countries is 27%, while those in middle and high-income countries is 62% and 78% respectively. Bangladesh, albeit in the early stage of urbanisation (e.g. 24%), has a high rate of urbanisation of around 6.8% per annum, as compared to those among the low-income countries - with 3.1 per cent in India, among middle-income countries - with 4.8% in Malaysia; and among advanced countries - with 0.3 and 1.5% in the UK and Australia respectively. The average annual urbanisation growth rates in the low, middle and high-income countries are 4.1, 3.2 and 0.8% respectively. A cross-country analysis of the data reported in the World Bank Report (1994) shows that only 7 out of the 132 reported countries have surpassed Bangladesh in terms of their urbanisation growth rates.

The current rate of population growth in Bangladesh is in the range of 2.2% per annum, which means that urbanisation is rising at more than three times the rate of population growth. The rapid population growth compounded by perpetual changes in the 'human-use system' (White et al 1974) has contributed to hazard effects by exposing more people and properties to risk, giving rise to ever increasing consequences. Comparative statistics (1992) for selected countries (Table 1.3) show that with a population of 114 million (1992), Bangladesh has one of the highest population densities (794 km^2) in the world, in marked contrast, for example, to Australia (2 km^2) or the United Kingdom (236 km^2). In terms of

Table 1.2: Comparative urbanisation evolution in selected countries of the world

	Urban Index1		Urban Index2	Urban Index3
Economies group	Urban share of total population(%)	Average annual urbanisation growth rate(%)	Capital city share of total urban pop(%)	Large towns' share of total urban pop(%)
Low-income	27	4.1	12	36
Bangladesh	24	6.8	37	56
India	26	3.1	4	34
Egypt	44	2.5	39	52
Nigeria	37	5.7	23	29
Middle-income	62	3.2	26	40
Philippines	44	3.8	32	36
Malaysia	45	4.8	22	24
South Africa	50	2.8	12	33
Saudi Arabia	78	6.5	16	28
High-income	78	0.8	11	43
Japan	77	0.7	19	47
United Kingdom	89	0.3	14	26
United States	76	1.2	2	51
Australia	85	1.5	2	72
World[1]	42	2.8	15	38

Note:
Urban Index1 and Urban Index3 refer to year 1992, and Urban Index2 refers to 1990.
Urban Index3 refers to large towns having population 1 Million or more.
Average annual urbanisation growth rate refers to period, 1980-92, except for Bangladesh, which applies to period 1981-91.
1 World includes 132 countries, for which data are available.
Source:
Compiled from World Bank Report (1994), Infrastructure for Development.

per capita income, Bangladesh ranks the lowest among the selected economies (Table 1.3). The most striking feature, however, is that even with the lowest per capita GNP, Bangladesh has an enormous GNP/km^2 ($175,000) - much higher than that of an average low and middle-income country, $32,000 and $56,000 respectively. This statistic for Bangladesh even surpasses those of some advanced countries, Australia for example. This implies a very high intensity of land development and area-wise concentration of crops, assets and properties in Bangladesh. In other words, it manifests immense competitive advantages of living in floodplains, perhaps partly justifying the high population density. This demonstrates that flood loss potential in Bangladesh is large.

The trend in Bangladesh's population and urbanisation growth is presented in Table 1.4. With an urban population of about one million in 1931, it is projected that Bangladesh will have an urban population of about 100 million by the year 2031. About 48% of the total population will then live in urban areas.

Against this brief background to Bangladesh, the rationale of the study is as follows. With a vast population living in a small area, per household arable land in Bangladesh is miserably low, estimated at only 0.75 hectares. The inordinate pressure on agricultural land has resulted in widespread unemployment and dismal poverty, especially in rural areas. The limited capacity of the agricultural sector thus 'pushes' labour into non-agricultural sectors. Especially with the rise in population and the decline in arable land, the agricultural community has to come under increased pressure to find ways of supplementing farm income through non-agricultural activities. Compounded by other reasons, this has induced widespread out-migrations to urban and semi-urban areas from rural areas, which 'is a key factor in the growth of vulnerability' (Davis 1981; 1987).

The trend in the contribution of major sectors to GDP (Table 1.5) demonstrates that the contribution of agriculture has decreased noticeably, from 47% in 1973-80 to 37% in 1993; the contribution was as high as 80% during early 1960s. On the other hand, the contribution from service industry has recorded a marked increase during the 1973-1993 period. The share of manufacturing has remained almost unchanged despite the emphasis on its development. Hence, the industrial sector has a large degree of unfulfilled development potential. Additionally, as the irrigated acreage cannot be increased indefinitely, the acceleration of growth of GDP in the long run depends particularly on the growth of

Table 1.3: Comparative statistics for selected countries of the world[1]

Economies group/ countries	Population size (Million) (1992)	Population growth rate (%) (1980-91)	Population density (Per sq Km)	Economic growth rate (%) (1980-92)	GNP	
					Per capita (US $)	Per sqKm (000 US $)
Low-income	76	2.0	82	3.9	390	32
Bangladesh	114	2.2	794	1.8	220	175
India	884	2.1	269	3.1	310	83
Egypt	55	2.5	55	1.8	640	35
Nigeria	102	3.0	110	-0.4	320	35
Middle-income	21	1.8	23	-0.1	2490	56
Philippines	64	2.4	214	-1.0	770	165
Malaysia	19	2.6	56	3.2	2790	157
South Africa	40	2.5	33	0.1	2670	87
Saudi Arabia	17	4.6	8	-3.3	7510	59
High-income	36	0.6	26	2.3	22160	579
Japan	125	0.5	329	1.5	28190	9285
UK	58	0.2	236	2.4	17790	4197
USA	255	0.9	27	1.7	23240	633
Australia	18	1.5	2	1.6	17260	39
World[1]	41	1.7	41	1.2	4280	175

Note:

[1] World includes 127 countries, out of which low income economies are 40, middle income economies are 65 and high income economies are 22 countries, for which data are available.

Source: Compiled from World Bank Report (1993; 1994; 1995).

Table 1.4: Trend in population and urbanisation growth in Bangladesh

Census year	National population (million)	Annual population growth rate[1]	Urban population (million)[2]	Urban population as % of total population	Average annual rate of growth[3]
1931	35.6	-	1.13	3.2	-
1941	42.0	1.7	1.35	3.2	1.9
1951	44.2	0.5	1.82	4.3	3.5
1961	55.2	2.2	2.64	5.2	4.5
1974[4]	76.4	2.5	6.27	8.8	10.6
1981	89.9	2.4	14.09	15.7	17.8
1991	111.5	2.5	23.74	21.2	6.8
2001[5]	135.2	1.9	40.00	29.6	6.9
2011[5]	162.2	1.8	58.80	36.3	4.7
2021[5]	187.0	1.4	79.10	42.3	3.4
2031[5]	208.5	1.1	99.60	47.8	2.6

Source :
Own estimates, compiled from BBS-SYB (1992; 1993); ADB (1994); World Bank Report (1985).

Note:
1 Exponential rate of growth.
2 Projected urban population figures assume 1% out-migration from rural areas.
3 Simple rate of growth.
4 The census undertaken three years after it was scheduled.
5 All figures for these years are derived from projection, as estimated by ADB (1994); World Bank Report (1985).
The average annual rates of growth indicate the estimated rate over the previous decade or the period since the last census.

Table 1.5: Major sectors' contribution to GDP in Bangladesh

Major sectors	Contribution in per cent in year			
	1973-80	1981-90	1988	1992/93
Agriculture	47.4	40.5	38.4	36.9
Industry	16.5	16.2	16.7	17.6
Services	36.1	43.3	44.9	45.5

Source:
Compiled from World Bank Report (1994)

Note:
Contribution estimated at constant 1985 prices.

industries, which are expected to grow in urban areas due to better infrastructural facilities[2]. All these might lead to yet a greater increase in the rate and level of urbanisation in the near future. International experience also suggests that the transition from low-income to upper-income developing country status is accompanied by a shift in the sectoral composition of employment away from agriculture to non-agriculture, particularly to industry and services. This shift is usually accompanied by 'significant population movement from rural areas to the cities so that a strong relationship exists between economic development and urbanisation' (Samuel 1986).

Potential urban flood losses are, thus, becoming more and more important and deserve greater attention. Whereas the rural and agricultural community can often cope with floods (e.g. through changes in cropping patterns), urban and commercial growth centres are not likely to have that degree of flexibility against floods. Controlled flooding is obviously not an appropriate strategy in urban areas, as often the case in agriculture. Protection of urban and commercial centres thus demands a high priority.

The linkage between urbanisation and flood impacts is interesting for at least two reasons. Firstly, flood losses would normally increase as more and more properties become prone to flood losses, owing to increased urbanisation. Secondly, urbanisation is expected to change the run-off regime by reducing the time of concentration of run-off. It is thus expected to increase flood frequency, flood peaks and flashiness. Hence, as development in general will continue, devising appropriate methods of potential urban flood loss assessment will be increasingly important in order to plan efficient urban development in relation to flood action. The link between urbanisation and flood hazards therefore requires an analysis in order to predict potential flood damages and required responses.

There has been massive investment in agricultural projects. As of 1992, more than 7000 kilometres of embankments have been constructed under as many as 451 FCD/I projects. These are basically aimed at reduction of crop losses. Ironically, very few schemes to protect towns or urban centres exist at present in Bangladesh. Research on flood losses in urban areas is now important. Unlike in many places, including England and Wales where floods are comparatively mild and of small scale, floods in Bangladesh are often catastrophic in

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[2] Urbanisation is viewed 'as an inevitable concomitant of industrialisation' (Ranis et al 1990).

terms of scale, impacts and coverage. An account of 'official' and 'reported' damages in three selected river floods and a few selected tidal surges are presented in Tables 1.6 and 1.7. It is evident that even 'official' damages to properties and infrastructure are colossal, although the full account of losses is not available. As many as more than 107 million people were directly affected in the three selected flood events. In one of the events, 1974, for example, several hundred thousands of people died in the famine, which is deemed to have resulted partly from indirect effects of flooding[3]. The full scale of damages caused by flooding is unknown but it is certainly large. The tangible and reported effects are estimated to range from 400 to 833 million pounds sterling (Table 1.6). For tidal flooding[4], the magnitude of the destruction is largely unknown. The death toll of up to as high as a few hundred thousand suggests the scale of property losses even in this poor country (Table 1.7).

Unfortunately, research on flood hazards is relatively recent and oriented mainly towards the USA, UK and Australia. Flood research in Bangladesh has been mainly limited to appraisal or evaluation studies which tend to focus on agricultural and rural losses. Almost no basic research, (with a few exceptions, e.g. Thompson 1990; Maurice and Diallo 1991) on flood impacts has been carried out. Research on urban flood losses in Bangladesh is important, especially in the context of potential 'diaster vulnerabilities' due to the rapid urbanisation process. Parker and Mitchell (1995b) suggest that:

> 'Because many megacities appear to be becoming increasingly vulnerable in disasters of all kinds, it is important to improve knowledge of the ways in which urbanization contributes to disaster vulnerability' (Parker and Mitchell 1995b:296).

It is thus important to improve the knowledge of how natural hazards magnified by urbanisation can cause havoc to lives and property. Ironically, hitherto there has been little research on methods of flood loss assessment for urban and non-agricultural losses.

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[3] Sen (1981) found that, even with no significant fall in food availability per head, 'lack of entitlement to food' with sudden price hikes associated with a major fall in employment opportunities was the main reason for the starvation, which occurred immediately in the aftermath of 1974 flood. See also Alamgir et al (1975a; 1975b); Alamgir (1980).

[4] A tidal flood usually results from a cyclone or storm.

Table 1.6: Estimates of major effects caused by three recent river floods in Bangladesh

Damage item	1974 flood	1987 flood	1988 flood
Areas affected			
Total area (000 Sq Km)	53	57	90
% of country affected	37	40	62
Districts affected (No)	20	50	52
Thanas affected (No)	90	347	318
Population			
Population affected (Mil)	30	30	47
Loss to human lives (No)	Several lacs[1]	1,657	2379
Crop			
Totally damaged (Mil Ha)	NA	1.23	4.26
Partially damaged (Mil Ha)	NA	.85	3.28
Livestock			
Cattle heads (000)	NA	64	172
Poultry (000)	NA	NA	410
Houses			
Totally damaged (000)	NA	989	2880
Partially damaged (000)	NA	1,478	4320
Infrastructure			
Metalled roads (Km)	NA	1,523	13000
Unmetalled roads (Km)	NA	15,107	66,000
Rail way (Km)	NA	NA	1303
Bridge/culverts (No)	NA	1,102	2,788
Educational Inst			
Totally damaged (No)	NA	NA	1,367
Partially damaged (No)	NA	NA	7,114
Industries (No)	NA	NA	1400
Business units (No)	NA	NA	NA
Flood embankments			
Totally damaged (Km)	NA	105	2500
Partially damaged (Km)	NA	1,074	NA
TOTAL DAMAGE (Mil £)	400	667	833

Source :Ahmad (1989); Rogers et al (1989); BBS (1993); Japan Ministry of Foreign Affairs (1989); Elahi (1988). 1 Lac = 100,000; deaths (1974) caused partially due to indirect effects of the flood, which was immediately followed by a wide-spread famine.

Table 1.7: Estimates of major effects of selected tidal surges in Bangladesh

Year (Month)	Storm wind speed (mph) /Max surge height (Metres)	Loss to human lives (Nos)	Loss to livestock (Nos)	Houses destroyed (Nos)
1970 (Nov)	138 mph 10 m	500,000	Large Nos	Widespread
1974 (Nov)	100 mph 5 m	20	1,000	2,300
1983 (Nov)	85 mph 2 m	300	NA	2,000
1985 (May)	96 mph 4 m	11,000	135,000	94,000
1988 (Nov)	100 mph 4.4 m	5,700	65,000	NA
1991 (April)	120 mph 7.5 m	150,000	70,000	NA

Source :BBS (1993); Chowdhury (1991).

Note: mph - Miles per hour; m - metre

Thompson (1990) thus suggested:

> ---in Bangladesh --- in improving project appraisals and in understanding the benefits and limitations of all flood mitigation choices, --to develop appropriate standard data bases so that consistent well informed decision making is possible (Thompson 1990:121).

The need for such data is well recognised: Burton et al (1978)) maintained:

> One sound basis for calculated action to deal with a natural hazard is accurate knowledge of the magnitude of property damage and loss of life, but perhaps even more pertinent for the evaluation of policy is knowledge of trends and the rate of change in such losses (Burton et al 1978:191).

A recently concluded Flood Action Plan (FAP-12 Study 1992a)[5] observed:

> ---there is a serious lack of reliable data on flood damages, particularly to property and infrastructure, but also to agriculture, from which to estimate flood protection benefits. Research is needed to provide a comprehensive data set and methodology which could be applied consistently across FCD/I project appraisals in Bangladesh-- (FAP-12 1992a:4-10).

Following the lack of damage data and methodology, the assessment of losses from floods made by various agencies and the government appears to has been based on arbitrary calculations which do not reflect any scientific basis. In order to 'deal with' a natural hazard such as flood, it is thus important to understand, reveal and categorise impacts, and it is important to generate a flood loss data base and to accumulate a 'sound basis' for the knowledge of the magnitude of the losses.

By definition floods or any natural hazards involve human being, nature and environment. In Bangladesh humans have few options but to live with flood hazards. There are then two options: first, to adjust and live in harmony with nature and second, to seek to control nature.

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[5] Following the disastrous floods 1987 and 1988, in collaboration with international agencies, the World Bank framed a Flood Action Plan (FAP), with 26 study components, towards development of a long term comprehensive system of flood control and drainage works. FAP-12, the FCD/I Agricultural Study, is one of these studies in which the author was involved, responsible for 'examining' non-agricultural impacts.

Comprehensive floodplain management often involves combining both harmony and control of nature. However, since the ability to control the basic natural processes (e.g. atmospheric processes producing most floods) is limited, human beings have sought adjustment strategies to reduce damaging impacts. However, flood losses have continued to rise. While there is a variety of reasons for this, it is increasingly recognised that there has been a persistent disregard for the human, social and ecological dimensions of the problem. Any flood research and floodplain management policy must address these problems.

A related issue is the distributional impacts that natural hazards have upon populations. In any economic analysis, or in the allocation of resources, two objectives most commonly confronted are efficiency and equity. Efficiency, defined as a level yielding maximum net social benefits (i.e. when marginal cost equal marginal benefits), is not expected to achieve equitable distribution of resources or to promote 'altruism' and a sense of community. Given the likelihood that a market system under certain conditions is able only to partially meet the objectives of equity, some interventions are necessary. Flood loss research and appraisal methods need to address both the issues of efficiency and equity.

Research experience demonstrates that poor people are more vulnerable than the well-to-do ones (Davis 1978; 1981; 1984a; 1984b; Blaikie et al 1994; Chan 1995). Intuitively, floods deepen poverty levels which may help widen the income gap between rich and poor. Who loses and who gains due to floods in the long run is thus a pertinent research question. The distributional effects of flood impacts are important because these are associated with sustainability of development. Many problems of sustainable development and environment 'arise from inequalities in access to resources'[6], and presumably these problems are deepened by existing poverty and the skewed distribution of resources in Bangladesh. It is therefore important to explore the vulnerability of individual households, enterprises and economic sectors in order to deal with the problems relating to sustainability of development, especially in the context of socio-economic conditions in Bangladesh.

The theoretical base of the research lies in the fact that the incidence of flood, and the damages caused thereby, is stochastic in nature. The return of floods at an uncertain interval of time follows the statistical probability theory. Total flood loss assessments are achieved

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[6] Brundtland Report (1987), Our Common Future (The World Commission on Environment and Development).

by combining the damage estimation for flood events with probability analysis of the range of possible floods of uncertain occurrence. The mathematical and statistical relationships of damages with flood variables are also the theoretical footings on which the present flood research is based. In particular, regression analysis techniques and input-output analytical tools are the foundations of the research. As appraisal methods and economic analysis of town protection schemes is one of the ultimate concerns of the study, the research is rooted in the benefit-cost analysis techniques, which involves a discounted measure of project worth.

Over the recent years, substantial flood researches have been carried out in countries including the UK, USA and Australia (eg White 1945; Parker and Penning-Rowsell 1972; Penning-Rowsell and Chatterton 1977; Parker 1976; Smith et al 1979b; Green et al 1983; Parker and Penning-Rowsell 1984; Parker et al 1987; Green et al 1988a; Thompson 1989). The British contribution to this has been quite significant, most of which, has been carried out in the Flood Hazard Research Centre at Middlesex University. The Centre is a chief source of extending the research support necessary for undertaking the study. The research benefits from the basic methods developed in the Centre, contained in the two most comprehensive studies, namely by Penning-Rowsell and Chatterton (1977) and by Parker et al (1987). These methods, have received widespread application in the countries including Australia and the USA (Greenway and Smith 1983; Higgins and Robinson 1981; US Army Corps of Engineers 1979; 1981). Inevitably, the perspectives on which the assessment methods are based are those of highly advanced societies. It is thus important that the research examines the applicability of the existing assessment methods to a developing country socio-economic perspective.

In spite of significant achievements on flood loss research, a striking feature is that the effects caused due to linkages, especially the economic ones, appear not to have received adequate attention in contemporary investigations. Especially in an urban economy, innumerable inter-dependencies exist among sectors and sub-sectors, which eventually give rise to external economies. Not surprisingly, in an economy such as the United Kingdom it is suspected that 'secondary impacts due to such linkages in the national context are likely to be insignificant', as the 'negative and positive effects will tend to cancel one another out' (Parker et al 1987)[7]. Nonetheless, there are few studies (except, perhaps, the one by Penning-Rowsell et al 1992b) which can demonstrate empirical evidence in support of or against this, at either micro or

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[7] Arguably, this could be so, as floods in the UK are generally of mild and local nature.

regional level. Following this, the linkage effects of flooding is an area of flood hazard research which merits more investigation.

Importantly, floods in Bangladesh are of different types. Although not all floods are harmful, some are severe, widespread and catastrophic. It is thus important to explore the differential impacts of flooding caused by the different types of floods.

1.3 Research Questions

Against this background, the research addresses the following broad questions:

1) Can the flood loss assessment methods developed in the advanced societies be applied in a developing country such as Bangladesh?

2) Are non-agricultural impacts important in Bangladesh, even though it is currently an agricultural country? If so, what effects does flooding have on urban or non-agricultural sectors and in what magnitudes? What sectors are critically vulnerable? What effects does flooding of agriculture, in particular, have on the industrial economy?

3) Are linkage effects of flooding important in Bangladesh? At what level - national, regional or firm level?

4) Is there any evidence of differential impacts caused by the different types of floods in Bangladesh?

1.4 Research Objectives

With these questions in mind, the broad objectives of the research are :

1) To apply the existing assessment principles, modified as necessary to a developing country perspectives, to a sample of urban floodplain occupants.

2) To generate potential flood loss data sets - the data sets which are to be used as an input into modelling flood protection benefits.

3) To reveal, conceptualise and categorise various urban non-agricultural impacts of flooding in Bangladesh, and thereby to acquire a sound knowledge of the magnitude of major urban impacts both at micro and macro levels.

1.5 Potential Usefulness of the Study

The present study on urban impacts of flooding generates appropriate potential damage data sets which may be used as a guide to appraise urban flood protection schemes. This will also help the evaluation of agricultural projects more comprehensively in future, through taking into consideration the non-agricultural losses that can be averted in agricultural schemes - the aspect of which has so long largely been ignored.

The knowledge of the vulnerability of urban sectors is expected to contribute towards a rational allocation of resources in a flood ravaged economy. This will facilitate identifying bottlenecks of industrialisation, in particular, with regard to flood losses. The information on flood hazards can be used as a sound basis for calculated actions, such as flood mitigation, warnings and emergency preparedness[8]. Apart from policy formulations towards protecting towns, the accumulation of the knowledge base should contribute to decisions about the selection and prioritisation of projects. The knowledge of the vulnerability of the various sectors and properties may eventually be used in policy formulation in land use and other regulations. In effect, this is expected to contribute towards a better floodplain management in the country.

1.6 The Plan of the Thesis

The thesis is organised in nine chapters along the major stages and the theme of the research. Starting with the background to the research, including aims and objectives, presented in Chapter 1, Chapter 2 presents a review of the existing flood research literature, followed by setting the conceptual foundations of flood impacts and their modelling. The chapter examines the loss assessment methods from various perspectives and outlines a set of broad principles of impacts modelling to be adopted in the present research. Chapter 3 presents the

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[8] The rationale of this research is recognised from the fact that while the study was in progress, the agencies such as FPCO (BWDB) and FAP-20 showed keen interest in obtaining the findings of the study, particularly the potential data sets generated, for their use in town protection appraisals.

methodological framework outlining how the study is actually implemented.

The subsequent chapters, Chapter 4 through to 6 present empirical results, employing methods and models developed, and generate appropriate loss data sets for major urban sectors. The other major component of the three chapters relate to the revealing of the impacts for each of the selected urban sectors and sub-sectors. While revealing the impacts, differential impacts of flooding in relation to flood types, property types, socio-economic factors, capital, experience, perceptions and warnings are all analysed. In each of these chapters, the vulnerability of the relevant sectors is discussed, and the important determinants of damages are identified. Linkage effects of flooding at the micro level are also dealt with in some detail. Chapter 4 deals with the residential damages, while Chapter 5 is concerned with business and industrial damages. Chapter 6 deals with damages to public buildings and the roads sector.

Chapter 7 presents a demonstration of the application of the flood loss data sets and assessment methods through an actual appraisal of a flood protection proposal for Tangail, the main case study town. In the appraisal process, the chapter deals with the land use and level survey, and frequency analysis followed by estimates of expected annual flood damage for the town. Chapter 8 analyses flood impacts at the macro level in relation to the two major economic sectors: agriculture and industry. Finally, Chapter 9 presents the major findings and policy implications of the research.

CHAPTER 2: FLOOD DAMAGE MODELLING - EXISTING METHODS AND THE PRESENT STUDY APPROACH

2.1 Introduction

This Chapter aims to provide contexts to the development of flood loss assessment methods and principles suitable to Bangladesh conditions. The chapter is organised in three main sections. The first section seeks to present a brief overview of the pertinent literature on various flood loss assessment methods. The problems of damage data collection and assessment are also discussed in this section. The next section discusses the basic loss models that are used in regional flood loss modelling. The third section aims to develop some broad principles to be adopted in the present research, in modelling flood damages for various urban properties in Bangladesh.

2.2 Review of Existing Literature

Flood research is principally centred around flood damages. Flood damages comprise broadly two groups, direct and indirect. Direct damages are physical and usually 'visible' losses arising out of direct contact with water (e.g. damages to house structure). Indirect impacts are the consequences of direct contact of property with water and are revealed through interruption and disruption of economic and social activities (e.g. production losses due to direct losses to machinery). Indirect effects can involve effects both in the short and long run. Indirect impacts, together with the direct ones, may result in a further chain of effects over time, called linkage effects. In yet another perspective - from the viewpoint of economic values - flood impacts are recognised as belonging broadly to two further categories: tangible and intangible. The tangible impacts are those to which a monetary value can be assigned in order to estimate them. Intangible impacts are defined as those which cannot directly be evaluated in terms of money[9].

Research on flood impacts and their modelling is carried out in a few advanced countries. The major contributing countries are the USA, UK and Australia. In the USA, the collection of flood damage information has been in practice as far back as 1902. In the UK, the practice started only in the late 1960s. Nevertheless, with the exception of the USA these

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[9] See, e.g. Parker and Penning-Rowsell (1972); Parker et al (1987).

countries started using these data for appraisal of flood alleviation schemes comparatively recently.

The following section presents an overview of flood loss literature on the residential and commercial sector, with a particular reference to assessment methods adopted.

2.2.1 Research on Flood Loss in Residential Sector

Research on flood impacts can be divided into three broad groups: (a) impacts assessment methods (b) depth-damage functions and data sets construction and (c) project appraisal methods. Broadly two approaches are adopted in flood loss assessments: surveys of actual floods and the synthetic approach. While the first approach involves damage assessments during or after the actual events, the second approach involves synthesising damage information from multiple sources, through constructing susceptibility matrices for different damage components.

In the USA, various federal agencies used to carry out rapid assessments of flood loss potential (so called 'windshield surveys'), from only an examination of the external appearance of the affected residential buildings (US Department of Agriculture, Soil Conservation Service, 1970). Flood loss potentials for future floods used to be assessed, or rather projected on the basis of actual events (US Army Corps of Engineers 1979[10]). The actual damages so assessed were used mainly for appraisals of flood control projects at regional levels, having no application at national levels.

The approach of extrapolating future damages from actual floods were subsequently modified, and the synthetic method of flood damage assessment started to be adopted in the USA. The approach initially developed by White (1964) and Kates (1965), was followed by the Tennessee Valley Authority (TVA) and the US Army Corps of Engineers (USACE). Both TVA (1969) and USACE (1970) concentrated on the generation of synthetic direct damage data in response to specific requirements of the federal flood insurance administration. The two agencies developed a series of depth-damage curves based on direct damages to a group of residences, the properties grouped according to aspects, e.g. number of rooms, storeys and construction materials. The susceptibility at each hypothetical depth for each house type was

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[10] The major federal flood control agency in the USA

estimated from different sources, e.g. relevant builders and manufacturers. These curves form the basis of estimating potential damages to different groups of residences, which were then generalised to similar residences in other areas of USA. James and Lee (1971) suggested an empirical linear function for shallow flooding, correlating damage with depth and property values. For a deeper flooding, they argued that the curve was likely to be of a non-linear form.

In Australia, Aitken (1976) regressed empirical residential damage data on depths of flooding and floor areas to predict future flood damage for the Brisbane river. The regression analysis, based on a sample of 400 households, derived the value of r^2 as 0.34 and 0.27 for the structural and contents damage respectively, was criticised by Penning-Rowsell and Chatterton (1977) for being too 'poor to be used in future damage assessments'. The low coefficients of determination in all the cases indicated, not surprisingly, the presence of a large variability in the existing damage data. However, given the large sample size and degrees of freedom, the coefficients of determination for all the cases were found to be statistically significant.

In the UK, methods of modelling damages to residential buildings used in the 1960s were rudimentary. For example, Porter (1970) assessed damages as a fixed percentage of property values. Yet crude in nature, during the early 1970s, the water authorities in the UK employed a flat rate, 10 per cent of property values, to represent losses in all depths of flooding. The Wessex Water Authority (1974) used an absolute rate of £500 per dwelling as potential losses, calculated on the basis of insurance payments for flood damages. Roberts (1968) was probably the first in the UK to adopt survey techniques to assess flood damage potentials. The approach was, however, criticised by Penning-Rowsell and Chatterton (1977) as 'notorious for underestimating past damage'.

Researchers, centred mainly in the Flood Hazard Research Centre, appear to have made a breakthrough in the field of flood loss modelling in the mid 1970s. After years of continuous research and development, a series of approaches and methodologies were developed. In the UK (and perhaps, USA), the assessment of potential flood damages based directly upon actual events was found to be impracticable for many reasons. The major reasons related to the scarcity of observable floods over various depths or durations and a large number of house types occupied by a large number of socio-economic groups. Consequently, the synthetic approach was adopted for the assessment of residential flood loss potentials (Parker and

Penning-Rowsell 1972; Parker 1976; Penning-Rowsell and Chatterton 1977).

The most comprehensive study of flood loss potentials in the residential sector in the UK is the one by Penning-Rowsell and Chatterton (1977), popularly known as 'Blue Manual'. Indeed, the study was a breakthrough in flood loss research in the UK, especially in the residential sector. The study adopted the synthetic approach in constructing nationally applicable standard data sets for various depths and durations. The depth variable has been explored for high levels of disaggregation, while, not surprisingly (in view of the UK flood characteristics), the duration variable has been highly aggregated. The high-level depth disaggregation has warranted fine-level damage estimates with the availability of fine-level hydrological information. However, the skewed distribution of samples over depths and durations posed limitations on performing statistical tests. Some of the methods and data have subsequently been revised and updated, incorporating technological and other changes (Suleman et al 1988). Fordham et al (1994) tested the fit of logarithmic functions for the residential damage, using interview data in the UK. The study correlated damages with depths of flooding in structural damages. For content damages, depths of flooding and the proportion of recovered losses were used as explanatory variables, in addition to 'time of flooding' which was used as a dummy variable.

2.2.2 Research on Flood Loss in Commercial Sectors

Research on flood losses in commercial sectors is centred around indirect losses, as assessment methods for direct losses are relatively straightforward. Hitherto, a limited number of studies have been carried out on commercial flood losses. Research on indirect losses is particularly meagre. Until recently, industrial flood loss potentials for future floods used to be predicted on the basis of actual events. This approach used to suffer from many estimation biases, such as those arising out of the tendency to record replacement cost rather than depreciated costs. Projections of indirect losses in future floods used to be made through obtaining crude ratios between direct losses and production disruptions (White 1964; Kates 1965; Smith and Greenway 1984b).

In the study of industrial losses in the Leigh Valley (USA), Kates (1965) found it methodologically difficult to obtain the relationship of production losses (indirect loss) with depths of flooding of past events. The study recognised that firm's financial losses were to be distinguished from national economic losses. The study also concluded that although the 'synthetic' approach is feasible, it is a highly involved task.

Smith et al (1979b) addressed flood damage assessment in the Richmond River Valley in Australia based on past floods. They largely adopted the assessment techniques developed by Penning-Rowsell and Chatterton (1977). The research succeeded in constructing depth-damage curves, by which future potential damages were predicted at disaggregated levels of depths and durations. However, the approach of estimating indirect losses based on the gross trading profit/turnover ratio method potentially led to an underestimation of true losses, as the best measure of indirect loss is value added on production lost. Additionally, the study has ignored production transfers and recoveries within the economy, which possibly led to an overestimation of indirect loss.

Taylor et al's users' guide (ANUFLOOD 1983) recommended that crude ratios of indirect to direct losses be used to project indirect loss in the future floods in Australia. This approach is fraught with the problem that damage characteristics and susceptibility to flood water are subject to changes in technological development in the production process. Parker and Penning-Rowsell (1981) criticised the approach saying that the 'ratios' are likely to vary 'between places and between return periods in the same place'. Thus, given that indirect losses as a whole are likely to be 'highly variable' (Parker et al 1987) due to different flood conditions and diversity in activities, it is almost impossible to appropriately standardise damage ratios.

The British methods of loss assessment in commercial sectors are based on interview techniques. The Blue Manual constructed depth-damage data for industrial enterprises in the study area of lower Severn (UK) based on site survey questionnaires. However, the study acknowledged methodological weaknesses and recognised the 'need for further research into these problems'[11].

Based on several researches, carried out mainly by the Flood Hazard Research Centre, a series of assessment methods were developed. The fundamental loss estimation method involved deriving damage estimates in hypothetical floods, based upon 'expert judgements' through interviewing industrial managers. The recent most pioneering research on loss

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[11] For example, the Blue Manual pointed out the problem of using full replacement of plant and equipment in producing direct loss data in manufacturing sectors.

assessment in commercial sectors is the one by Parker et al (1987), popularly known as 'Red Manual'. The study devised methods with special reference to indirect losses, the aspects then least covered in terms of research. This study also addressed flood loss potential in other sectors of the urban economy, e.g. communication, life-line outages and emergency services. The level of analysis ranged from preliminary desk-based to refined-level analysis and used area of the premises for standardisation. The research overcame many problems associated with the approaches used in past research. The study distinguished national economic losses from firms' financial losses, through incorporating production transfers within economy. It also addressed the problem of over-estimation of direct loss potential through incorporating average remaining values. However, the estimates of damages were heavily dependent upon management personnel and are likely to be subject to 'personal' bias, especially where respondents have no prior flood experience.

As for linkage effects of flooding or multiplier effects, research has been far more limited. Conventionally, benefit-cost analysis takes account of national economic losses, and it is argued that multiplier effects are likely to be counterbalancing in many economies[12]. In an earthquake study, Ellson et al (1983) concluded that the long-term regional economic impact of earthquakes upon major urban areas in the USA may in fact be positive, compared to a 'without earthquake' case. The intensive mobilisation of resources into the affected region in the process of recovery and restoration could be the major factor leading to this conclusion. Likewise, Grigg and Helweg (1975) (American Water Resources Association) argued that in the USA, 'the secondary impacts tend to be offset by secondary benefits', and thus recommended that such impacts are excluded from appraisals. There seem to have been very few empirical studies to support this conclusion, either at the micro or macro level. Exceptions are the study by North and Bibby (1990) which contemplated secondary indirect impacts (e.g. income and employment multipliers) in the Herne Bay coastal region; and the study by Penning-Rowsell et al (1992b) assessed 'knock-on' effects of the flooded economy on a wider regional economy in terms of employment and income.

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[12] Such as, in the United Kingdom, where intuitively multiplier effects of flooding are insignificant. For example, the Home Office of the United Kingdom suggests that 'secondary losses arising from production losses in fire events are likely to be small' (P A Management Consultants Ltd) (Parker et al 1987).

2.2.3 Problems of Damage Data Collection and Assessment

The review of literature suggests that the assessment of flood damages, which is *sina qua non* to flood defence appraisal methods, has long been a formidable task. For the economic analysis of any floodplain management, the single most essential figure is the estimate of Expected Annual Damage (EAD). The estimate of EAD for a stream reach involves four major inputs (1) the elevation of properties (2) stage-frequency curves for the stream reach (3) potential damage information for properties and (4) land-use category of the properties. Among these, flood damage assessment is recognised to be the major outstanding technical problem.

Flood damage assessments involve two principal techniques: synthetic techniques and stage-damage curves. The techniques of deriving stage-damage curves comprise two types: one is through historical damage data and the other, through empirical damage data. Because adequate damage data from past floods are difficult to find, flood damage assessment tends to be based on two approaches - actual flood damage assessment approach and synthetic approach. The advantages and disadvantages of the two approaches are discussed below.

2.2.3.1 Actual Flood Damage Data Collection and Assessment

Despite the fact that the approach of damage assessment through surveys of actual floods contributes to a vivid knowledge of flood effects, the approach is beset with practical problems. The most serious problem is that actual damages do not reflect potential damage because of the varied extent of damage-reducing measures undertaken by floodplain users. Conversion to potential damages through appropriate adjustments for varying extent of damage-reducing measures is a cumbersome process.

Damage data collection based on actual events through interviewing is dependent upon occurrence of flood events. The generation of data sets at disaggregated levels of depths and durations is often not feasible mainly because of the lack of adequate variations of depth and durations in a specific flood in a given area. Stable depth-damage curves are difficult to establish in these circumstances.

The memories recall problem, especially for householders who are not expected to maintain day-to-day accounts, poses a serious problem in generating damage information from a past event. Many effects of flooding take fairly a long time before they become apparent to victims. In view of the time-lag between the occurrence of floods and the emergence of medium and long term adverse impacts, it is not feasible that damage data are collected during or immediately after floods. Additionally, the interview method of data collection is beset with the problem of response and non-response error. Response errors include advertent and inadvertent bias that may lead to over- and under-estimation of the damages, while the non-response errors usually include sampling errors.

More often than not, the properties under investigation vary to a great extent in type and quality so that damages are subject to large variations. The sampling procedure for constructing the 'average' data from actual surveys thus requires a scientific approach, which is often expensive. There are also other limitations. Not all damages can be estimated by interview methods. Damage assessments to sectors, utilities, roads and emergency services for example, require a different assessment approach.

2.2.3.2 The Synthetic Approach

One of the alternatives to actual damage assessment is the synthetic approach - the approach of synthesising damage information from multiple sources. The major advantages and disadvantages of synthetic, average and site survey data are outlined in Table 2.1. The major advantage of synthetic data construction, as opposed to the actual survey data, is that these barely need any adjustments for damage-reducing measures. Besides, the approach is independent of occurrence of floods and barely requires sampling procedures. Synthetic data allow wider applicability than the average data generated by actual surveys. Nevertheless, the synthetic approach is also not free from bias arising from response and non-response errors, often compounded through multiple sources. Although Penning-Rowsell and Chatterton (1977) suggest that post-flood surveys are 'notoriously unreliable' to estimate actual damages 'until months after the event', it can be argued that the synthetic approach is subject to bias in that it uses various secondary sources in making flood susceptibility estimates of various damage components based on respondents' ability to do so. The most serious demerit of the approach is that the method is expensive in terms of resource and time.

Unlike in the synthetic approach, the respondents in a survey of actual flood damages are often more cooperative, in their willingness to respond freely about their own problem and about how they adjust after the event. Surveys of actual floods can also reveal intangible

Table 2.1: Comparative advantages and disadvantages of different type of standard flood damage data

Factors	Synthetic data	Average data	Site survey data
Cost	Expensive	Relatively less expensive	Least expensive
Time	Time consuming	Relatively less time consuming	Least time consuming
Data requirement	Dependent mostly on secondary sources	Dependent on large survey	Dependent on site survey
Bias	Usually + Bias likely, eg from insurance claims	Both + bias & - bias likely; likely to cancel out	Both + bias & - bias likely; likely to cancel out
Sampling error	Little	Arises	Arises
Response error	Usually little	Large	Large
Sampling technique	Does not arise	Needed	Needed
Recall problem	Does not arise	Arises	Arises
Damage category	Usually tangible impacts feasible	Tangible & intangible feasible through interview	Tangible & intangible through interview
Damage type	Concerns mostly direct impacts	Both direct&indirect impacts feasible	Both direct&indirect impacts feasible
Flood variables	Depth, duration considered	Other factors can be crudely captured	Other factors can be crudely captured
Structural damage	More suitable in advanced countries, not for Bangladesh.	Feasible but large sample required-regression can solve some problems	Large sample required
Inventory data	As above	As above	As above
Business loss data	Generally not feasible without interviewing	Feasible, but large sample needed because of large variations	Generalised data feasible
Level of estimates	Usually refined	May be refined, but usually intermediate scale	Usually crude
Applicability	Wider applicability	Wider applicability	Locality specific
Regression analysis	Not logical	Provides logical estimates	Less feasible
Generation of disaggregated data	Complicated	Less complicated through regression	Usually not feasible
Damage below floor level	Less complicated	Complicated	Complicated
Sampling distribution	Less effects of skewness	Large effects of skewness	Large effects
Outlier	Easy to verify	Difficult to verify	Difficult to verify
Adjustment for damage-reducing activities	Not needed	Can be adjusted	Can be adjusted

impacts, a feature which the synthetic approach can scarcely deal with. Despite its many limitations, thus, the approach based on surveys of actual damages is likely to be more realistic in predicting future damages.

2.2.4 Flood Research in Bangladesh

In Bangladesh, especially in non-agricultural sectors, there is no attempt yet to systematically collect flood damage data. Ironically, hitherto there exists little basic research on flood losses and their assessments methods, in either urban or non-agricultural losses. With a few exceptions, flood research has been mainly limited to appraisals or evaluation studies in the form of reports which focus largely on agricultural losses.

In his well-known book entitled, 'Poverty and Famine - an Essay on Entitlements and Deprivation', Sen (1981) concluded that lack of entitlements to food due to 'loss of employment associated with the lack of purchasing power, not the food shortage', was the main cause of the famine which followed the devastating 1974 flood. It can, however, be argued that the losses of employment and lack of purchasing power were indirect effects caused partly by widespread flood in that year.

Paul (1984) studied post-flood agricultural adjustments. The study concluded that floods are not necessarily harmful. Normal floods are rather beneficial to agriculture. Abnormal floods, however, cause adjustment problems to farmers. Montgomery (1985) studied crop losses caused by floods, through analysing deviations from trend. Murshid (1987) assessed the relative role of weather hazards and technology (seed-fertilizer-water) in affecting the output instability of foodgrain. The study concluded that weather-related factors are still dominant in Bangladesh agriculture.

The study by HIID/ESCAP (1988), sponsored by the Planning Commission, carried out an extensive survey in order to assess flood damages and their distributional impacts caused by the 1988 flood. Employment and output multipliers have been constructed by using the national I-O table. One of the important conclusions of the study was that the poor are more vulnerable to floods. The extent of distress sales by the poor was about 2.5 times that of the non-poor.

The study by Shahabuddin (1989),, based on his PhD research, included econometric models to delineate the role of risk in the resource allocation of small farmers in Bangladesh. The French Engineering Consortium (1989) studied macro economic effects of flood control projects in Bangladesh. The study inferred that the average annual cost of flooding on GDP is in the range of 0.8%. Hossain (1990) analysed fluctuations (from estimated trends) in foodgrain productions at the national and regional levels to explain the production instability caused by natural hazards.

The study by Thompson (1990), which is a follow-up research of his PhD dissertation, has reviewed existing appraisal and evaluation methods, and suggested various improvements to such methods, particularly in relation to flood control agricultural projects in Bangladesh. The study suggested that appropriate standard data bases be developed towards an improvement of project appraisals and understanding of the benefits and limitations of flood mitigation choices in Bangladesh. Azam (1991) suggested a multi-sector growth model in order to analyse macro economic impact of the FAP in the short and long run, with special reference to the impact of risk on the growth path. Maurice and Diallo (1991) attempted to quantify the macro-economic impact on growth prospects. The study recommended that the long-term impact on growth prospects be taken into consideration along with the standard method of economic analysis when evaluating flood control projects in Bangladesh.

2.2.5 Bangladesh Flood Action Plan (FAP)

The strategies and options for flood control in Bangladesh have been debated for many years. Following the proposal of a Master Plan prepared in the mid-1960s, some major embankments combining the functions of flood control, drainage and irrigation were built along the banks of the main rivers. With the wide-spread advent of small scale irrigation since the early 1970s, the strategy of water control tended to change to construction of small-scale early implementation projects (EIP) that could provide rapid results towards mainly protecting agriculture. Since then, the issue of flood control has been frequently overlooked. However, the 1987 and 1988 floods - the most severe floods on record in Bangladesh, created awareness both at home and abroad and called for solutions. Subsequently, in collaboration with a few foreign countries, the World bank framed a Flood Action Plan (FAP) for the development of a long term comprehensive system of flood control and drainage works.

Covering a five-year period 1990-95, the Flood Action Plan in all comprised 26 components, concerning planning, supporting activities, high priority projects and regional studies which are expected to provide grounds for setting the foundations of the long-term program. Some of the studies are completed while some remain in progress. The reports and studies so far represent different approaches to the flood problem.

FPCO (1992a, FAP-12) and FPCO (1992b, FAP-13) evaluated 17 completed FCD/I projects, using formal survey methods and rapid rural appraisal methods, the former concentrating on agricultural impacts and the latter on operation and maintenance. FAP-12 stressed the need for research to provide a comprehensive data and methodology which could be used consistently across FCD/I project apprasilas in Bangladesh. FPCO (1992d, FAP-14) aimed at assessing the flood response practices adopted by floodplain users. The GOB-UNDP (1989) and the GOB-Republic of France (1989) projects emphasised comprehensive structural solutions, recognising the needs for major drainage works along with the construction of flood embankments. The approach of control flooding was also recommended in some areas to facilitate normal agricultural crops and ground water recharge. Rogers et al's (1989) Eastern Waters Study analysed the drawbacks of various structural measures for controlling floods. The study observed that the construction of embankments and dams are less feasible - in economic, technical and ecological terms than other methods. The study presented a series of alternatives emphasising non-structural measures. The Japan Ministry of Foreign Affairs (1989) found it important to protect some urban centres and areas, including the capital city.

2.2.6 FAP-Project Assessment Guidelines/FAP Urban Protection Studies

There exists a number of documents in the form of guidelines on appraisal methods and economic analyses for FCD/I projects. These are, among others, FPCO Guidelines for Project Assessment (1991a; 1992e); Shahabuddin and Rahman (1992); MPO Investment Analysis Model (1991); and GOB-Republic of France's Pre-feasibility Study for Flood Control in Bangladesh (1989). It is important to present at this stage a brief description of the guidelines on appraisal methods, recommended in these documents in order to provide the rationale of the current research.

FPCO Guidelines (1991a; 1992e) are designed for the principles to be used in economic and financial analysis of investment projects under the Flood Action Plan. The guidelines, however, concentrate on the evaluation methods of agricultural protection schemes that are principally aimed at reducing potential crop losses. The document is based on the standard techniques of cost- benefit analysis (in relation to e.g. cropping pattern, costs of production, economic prices of agricultural commodities, and conversion factors) of agricultural investment projects, as used by organisations such as the World Bank. Annex-3 of the document outlines some general principles on the post-project assessment of non-agricultural/fisheries flood damage, principally concerning direct benefits from flood protection in 'with' (W) and 'without' (WO) situations. The guidelines delineate the widely accepted principles of estimating mathematical expectation of annual flood damage in W and WO cases, without spelling out any assessment methods/principles whatsoever of how to assess the non-agricultural damages (e.g to residential and commercial sectors). Nonetheless, the direct damages (e.g. to embankments and roads) are recommended for inclusion in the economic analysis. It is, however, suggested that 'direct' loss data are collected from secondary sources such as relevant Ministries/Agencies (e.g. MRR, MLF, BWDB). In particular, it is suggested that the damage data on fisheries be collected from District or lower level, available in summarised forms from the Ministry; a careful scrutiny, however, is stressed to 'reconcile inconsistencies and inaccuracies' in such data. It is also suggested that the damages caused due to economic and social interruptions of activities are 'difficult to assess and should not be included in the analysis'.

The document, GOB-Republic of France (1989) (Pre-feasibility Study for Flood Control in Bangladesh) strongly suggests that the indirect benefits induced by flood protection/control to non-agricultural sectors be considered. The study maintains that although Bangladesh is generally well furnished with statistical information and documentations, the information in regard to flood damages (on particularly non-agricultural sectors) are 'incomplete, inconsistent and partially incorrect'. As also discussed in Chapter 1 on the rationale of the current research, the assessment of such losses in Bangladesh has been based on arbitrary calculations without representing any scientific basis. There is no systematic way of collecting flood damage information on annual basis on particularly non-agricultural sectors. Only in exceptional floods are some loss assessments carried out on an adhoc and emergency basis 'with a view to mobilising external and internal support'.

However, GOB-Republic of France (1989) suggests that flood damages be collected from various 'reports' 'prepared' by various institutions and agencies, who generally maintain the damage records in physical, but not in monetary terms (e.g. number of people affected, houses damaged). As the records are largely prepared based on visual assessments of affected properties, it is suggested to 'review and analyse such data cautiously' before using this. It is recommended to use 'best possible guesses' from damage records of past floods, in appraising flood protection projects.

Shahabuddin and Rahman (1992) is a well-documented guide, however, dealing with various costs, such as economic prices of selected commodities and conversion factors for use in FAP planning purpose. MPO-Investment Analysis Model (1991) is another well-documented guide, but dealing with allocation of investment funds year by year for FCD/I projects ensuring a selection procedure from a set of investment alternatives. The model concerns only benefits from agricultural cropping.

Hence, few guidelines on methods of loss assessments, let alone for urban and non-agricultural losses, are covered in any of the guidelines.

FAP Urban Protection Studies

In the recent past, a number of feasibility studies for town protection has been carried out (FPCO, FAP-8A 1991b; FPCO, FAP-8B 1991c; FPCO, FAP-9A 1992f; BWDB, FAP-9B 1992; GOB-UNDP, 1992). The projects have largely differed in their primary objectives. FPCO (FAP-8A 1991b) is a master plan for protection of Dhaka metropolitan area. FPCO (FAP-8B 1991c) is a feasibility study of environmental management plan for Dhaka city, the major component being the development of low-lying and slum areas around the city. FPCO (FAP-9A 1991f) is a secondary towns integrated protection with four project components of which the flood protection is one. BWDB (FAP-9B 1992) is primarily concerned with protection from erosion. GOB-UNDP (1992) (Multipurpose Cyclone Shelter Programme) is not a flood protection scheme, but it aims at determining cost-effectiveness (as compared to public expenditures elsewhere) of constructing shelters of multiple use. The principal benefit amounts to the human and animal life savings during storm-surges, and the use of the shelters as primary schools during the remaining period. The other damage savings, if any, are not considered in the analysis. Because of various primary objectives the studies mentioned above adopted varied methodologies in the assessment of protection benefits.

In order to provide contexts to the development of flood loss assessment methods and demonstrate the justification the current research it is important to examine the methods adopted by these studies in assessing flood losses in non-agricultural sectors. The review that follows applies almost to all the above studies; special reference, however, is made of the relevant studies where appropriate. Nevertheless, the present discussion concentrates on the methodology of benefit assessment from flood protection. In general, the methodologies on loss assessments (ie benefits of protection) adopted by the studies appear to have suffered from many weaknesses. However, only a few main points are outlined in the following brief discussion.

Most studies have sought damage information from 'records' of past floods. An important limitation is that, in none of the studies, potential loss data sets by depths or durations, by sectors or sub-sectors are constructed. No land use survey by sub-sectors (commercial activities) or by house types (residential sector), nor any hydrological survey to determine vulnerability of individual properties is carried out. The studies use only limited land use information, collected largely from secondary sources. As demonstrated in Chapter 7, the information on land levels and heights of properties are crucial to the precision of flood protection benefits. As revealed in Section 7.2.2.1 (Chapter 7), flood loss estimates are very sensitive to small changes in flood levels of properties. However, in none of the studies any such land level or height surveys are undertaken. In consequence, the benefit assessment without any knowledge of the extent of inundation (in terms of depths or durations) caused to various types of properties by a range of floods has certainly led to gross errors.

Following the lack of standard potential loss data sets in Bangladesh, the study FAP-8A has sought linear relationships of damage ratios (to values) with depths and durations for 1987 and 1988 flood, which appears not to be logical. As will be explained later in Chapters 4 and 5 (Sections 4.2.6 and 5.1.6), a linear function is likely to be unsuitable in that it yields damages even for a zero depth or duration of flooding. Additionally, in such a function the possibility of satiation of damages in varying depths or durations is ignored. More importantly (as explained e.g. in Sections 4.2.1 and 5.1.2), unless any groupings to properties under investigation by homogeneity are carried out, no stable relationships are likely to exist, as there exists a great diversity in their type, stock, capital and thus damage dimension across various properties. In the commercial plants investigated in the current research, for example, enormous variations are manifested, at times a few hundred times, across various types of enterprises (See Section 5.1.2 in Chapter 5).

The study FAP-8B relies mainly on the loss estimates and their assessment methods adopted by FAP-8A. The study also uses limited damage information collected from secondary sources. Almost all the studies (8A, 8B and 9B in particular) use flat rates (fixed ratios) to assess damages to properties regardless of type and size of properties in each of the sectors. One of the most serious limitations relates to that the studies have not distinguished actual event damages from potential damages. The actual damages (which is indeed a part of the full potential damage), either in absolute or proportional terms, are not suitable to exhibit functional relationships with depths and durations, as there exists varied extent of damage reduction measures adopted by various flood plain occupants. The studies generally have not properly distinguished, if at all, between financial and economic losses to properties. Another limitation is that the studies generally have not incorporated 'average remaining values' while estimating flood damages. This will be associated with substantial over-estimation of damages, because, if a damaged inventory, for example, is replaced after flood, full replacement value is not the flood damage. One needs to consider the depreciated value in the pre-flood situation (See Section 4.2.2 in Chapter 4 for more details).

The income loss in households and profit loss in commercial enterprises are not the true reflection of indirect flood damages (8A; 8B). The production loss in industries amounts to the loss to value added, and the turnover loss in business amounts to the loss to gross margin (Parker et al 1987). Over and above, as adopted in the studies, the income losses in households and profit loss in commercial enterprises have every potentials of being double counted. Indeed, the direct and indirect losses (let alone multiplier effects) caused to enterprises or households have not been properly defined or distinguished. Generally, flat rates are used to represent income losses to commercial (industrial and business) enterprises, as a whole.

In estimating indirect losses particularly, no consistent methodology is followed. A serious limitation is that output recoveries, trade adjustments and the transfer of losses have not been accounted for in the studies (For a discussion on indirect loss-assessment principles see Section 5.1.3.4). In industrial/business enterprises, damage to machinery/equipment and inventories are pooled together (8A), and flat rates for the sectors as a whole are used, which is subject to significant errors as machinery and stock have completely different susceptibility to inundation.

FAP-9A, as already mentioned, contains flood protection as one of the four components. The major component is drainage, low-lying areas development and environmental improvements. Following FAP guidelines, the study uses land use and damage information (by broad sectors) from secondary sources. In damage assessment, the study considers mainly structural damage, represented by fixed ratios, irrespective of any size and type of properties. The current research, as will be seen in subsequent chapters, clearly shows that the variations of susceptibilities and damages, both within and among groups of properties, are enormous. This is more so for business and industrial enterprises. Similarly, flood damages are significantly different (at times many-fold) among different socio-economic class of households and size and scale of commercial enterprises. Most studies use flat rates to assess damages. The study, FAP-9B, for example, uses fixed ratios e.g. 15% and 25% to assess total flood damages to residential and commercial sector respectively. Even business and industrial enterprises are not distinguished. The use of flat rates across all properties (commercial - across business and industries, households - across all socio-economic groups) inevitably leads to a considerable over-estimate of benefits, as, for example, damage ratio for a low-cost house type is many-fold compared to that for a high-cost house. The most serious limitation of the methodology adopted in the studies relates to the use of average depths or durations of inundation by zone/area, which inevitably leads to serious errors in the benefit assessment.

In FAP 8-A, only two flood scenarios (e.g. 1987 and 1988) are considered while estimating damage-frequency curve, the curve which is crucial to the precision of expected annual damage. There are other drawbacks as well. For example, the 1987-scale flood appears to have no flood impact on building structures of business, office and industrial enterprises, although depth of inundation to such properties ranges up to 1.7 metres and duration up to 32 days depending on the land use, which is unusual.

In aggregate, the feasibility studies appear to have not been based on sound and consistent methodologies and damage data, in consequence of which the benefit assessment appears to have been subject to considerable errors.

2.3 Existing Loss Models

This section presents a brief discussion of regional flood loss models having potential uses in project appraisals. Three basic loss models have been in use for regional loss modelling: (a) regional econometric models (b) unit-loss models and (c) input-output (I-O) models. The regional econometric model and the input-output model are largely used in earthquake impact modelling, and almost certainly, the unit-loss model is used in flood loss modelling.

2.3.1 Regional Econometric Models

The regional econometric model, developed by Ellson et al (1983), uses housing stock damages (units destroyed), and then assesses losses by comparing regional econometric activities with and without an event. Almost invariably, the model uses I-O tables to determine the effects on the total economy by adjusting the outputs of the affected sectors.

2.3.2 Unit-loss Models

The unit-loss model, initially developed by the American researchers, was later adopted by researchers in the UK and Australia (Penning-Rowsell and Chatterton 1977; Smith et al 1979; Higgins and Robinson 1981; Parker et al 1987). The model involves, first, identifying flood prone properties according to their land uses, and estimating individual property floor heights. Through an interactive computational model the model then employs standard potential depth-damage data and frequency analysis of flood levels, to estimate the total flood damage potentials in the area under study for floods of various magnitudes. The model has recently received widespread use in appraising flood alleviation schemes both within and outside UK (Figure 2.1).

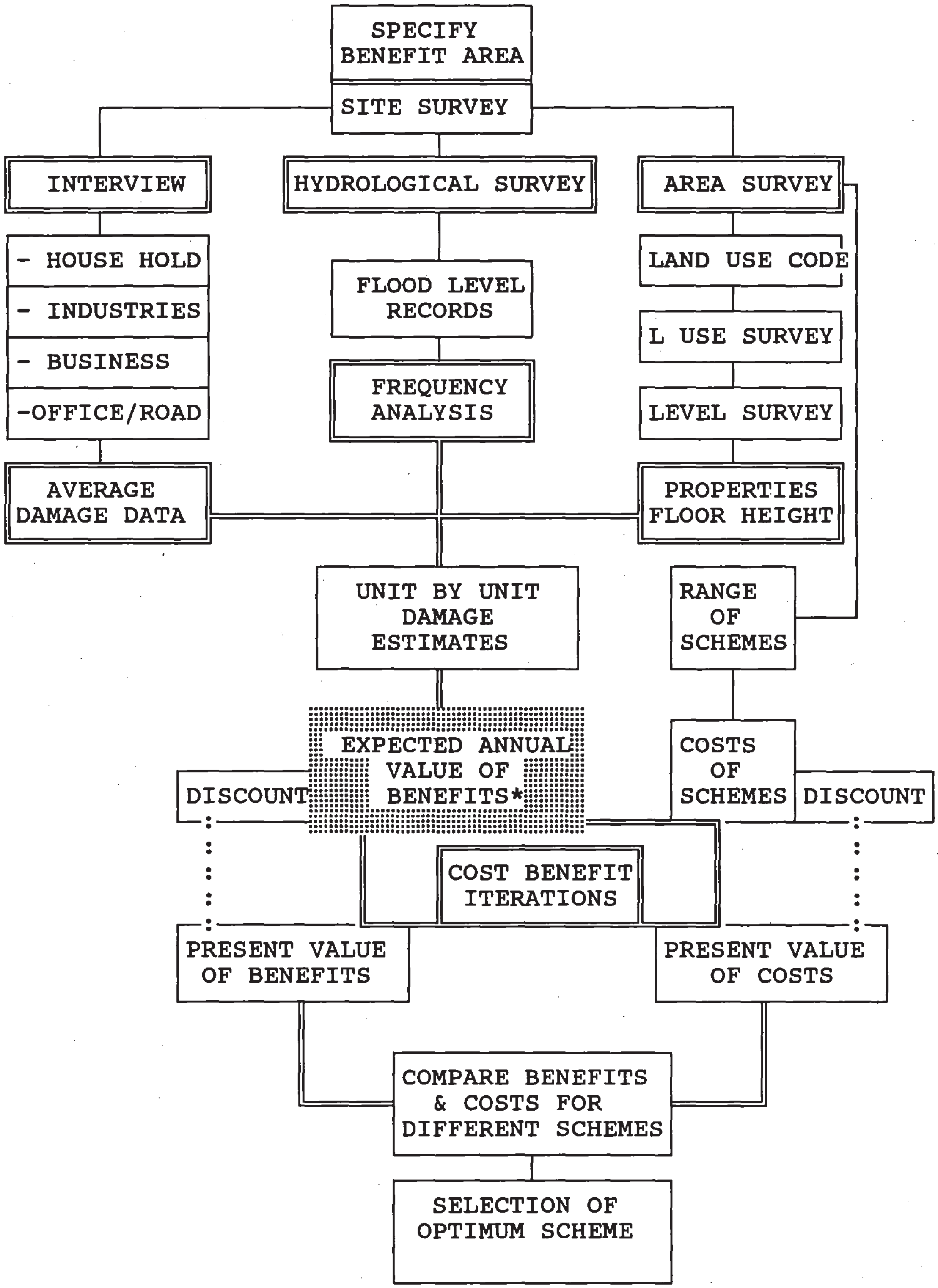
2.3.3 Input-output Models

Input-output models are used for modelling impacts through inter-relationships among industrial sectors in an economy. The impact of a primary fall in output in industries upon the economy is assessed through this model. The model is based on input-output tables, national or regional. In essence, the model is not used to assess primary impacts, but used to assess the 'knock-on' effects (multiplier effects) of primary impacts.

Comparative Advantages and Disadvantages of Loss Models

Comparative advantages and disadvantages of the three models are presented in Table 2.2. One of the principal advantages of the econometric model over the unit-loss model is that it can model the full range of impacts, direct and indirect, and can estimate the expected trend in the whole economy. The model, rarely used by British flood researchers, has been criticised by, among others, Penning-Rowsell and Chatterton (1977), Parker et al (1987) and one of the pioneers of the model, Ellson (1983) himself. Parker et al (1987) argued that the

Figure 2.1: Unit-loss Model (modified from Parker et al (1987))



* Tangible benefits

PRINCIPAL CONCERN OF THE PRESENT STUDY ▨

Table 2.2: Comparative advantages and disadvantages of loss models

Factors	Regional econometric model	Unit-loss model	Input-output model
Data and source	Time series data from secondary sources	One-shot field survey data	Time series data from secondary sources
Hazard scale	Large scale	Small scale	Small & large scale
Adjustment of recovery and damage-reduction	Incorporation difficult	Incorporation feasible	Incorporation not feasible
Trade adjustments	Incorporation not feasible	Incorporation feasible	Incorporation not feasible
Supply side factors	Cannot adequately capture	Can capture	Cannot adequately capture
Range of impacts	Model almost full range of impacts	Model direct & primary indirect impacts	Model only multiplier effects
Level of estimates	Usually not much refined	Usually relatively refined & disaggregated	Not refined
Damage category	Tangible impacts feasible	Tangible & intangible feasible	Tangible impacts feasible
Vulnerability assessments	Assessment not feasible	Assessment by impact/sector/area feasible	Assessment not feasible
Depth-damage/loss-probability relationships	Not feasible	Feasible	Not feasible
Appraisals of range of protection	Not feasible	Feasible	Not feasible
Hazard applicability	Mostly earthquake modelling	Mostly flood loss modelling	Mostly earthquake loss modelling

model is 'most unlikely to be capable of the fine-level estimation of flood damages, often required in flood hazard management'. Ellson et al (1983) faced the problem of using input-output tables in modelling losses in that they tend to 'exaggerate losses from catastrophic events unless the effects of recovery process are properly incorporated'. The most important limitation of the econometric model is that it cannot easily model losses caused by floods of various magnitudes, so that frequency analysis cannot be performed resulting difficulties in assessing expected annual benefits of protection.

The principal advantage of the unit-loss approach over the regional econometric model is that it can provide fine-level estimates for damages, disaggregated over spatial and sectoral properties, even unit by unit. More importantly, the model is capable of separating impacts by types, flood levels and frequencies - even when flood level and frequency differences are small. The model is thus capable of appraising benefits for a range of flood protection standards, a feature which is inconceivable by any other models. The model has limitations. The most important limitation is that the model is inappropriate to be applied to large-scale floods or wider regions. The model is demanding in terms of resources, time and data, particularly in respect of high quality hydraulic and hydrological information, the information which most regions often lack. The model is unsuitable for capturing regional impacts in a wider economy, for which regional econometric models are more suitable.

Input-output models are not independent models, but are usually used to assess total impacts in combination with regional econometric models. The researchers namely, Cochrane (1982), Higgins (1981), Higgins and Robinson (1981) have recommended input-out models to assess the effects of disruption in outputs on the total economy. But, based on input-output tables, regional or national input-output models are heavily dependent on data from secondary sources. The models fail to adequately deal with supply side sectors (e.g. transportation). Additionally, these models which are based on fixed input-coefficients, fail to incorporate recovery activities and to portray long-term economic impacts of catastrophic events.

2.3.4 Non-flood Models

Recent years have seen a growing number of non-flood impact studies, especially earthquake loss studies. Although regional econometric models are generally used in modelling earthquake losses (Ellson et al 1983; Munroe and Ballard 1983), some researchers adopted slightly different approaches for modelling these losses. The analyser used data collected from secondary sources. Kuribayashi et al (1985) derived a loss estimation model of long term economic effects of earthquakes, using multiple regression analysis. Kawasima and Kanoh (1990) derived a method of estimating indirect effects associated with production losses caused by the Nihonkai-chubu earthquake: secondary 'ripple' effects were, however, estimated through input-output analysis. The primary economic losses were evaluated based on a model similar to the Cobb-Douglas production model. Munroe and Ballard (1983) derived a methodology for assessing indirect effects on income and employment. They analysed how an area, although not being situated in the affected zone, has been economically affected from spill-overs of an earthquake into the neighbouring zones.

In summary, the regional econometric models, in combination with input output models, are more appropriate for large-scale events, and are capable of assessing full range of impacts, including multiplier effects. However, these models are constrained by scarce time series data. Unit-loss models are useful in providing fine-level estimates for damages, disaggregated over depths, durations, sectors and impact types, through investigating losses unit by unit. The above discussion leads to conclude that unit-loss models, despite the limitations, are more suitable to most flood loss modelling.

2.4 Broad Principles of Flood Loss Modelling Adopted in the Present Research

As argued in Chapters 4 and 5, in Bangladesh the synthetic approach of flood loss assessments is infeasible because of the lack of secondary sources from which to synthesise information. Instead the research seeks to model flood losses based on surveys of actual floods through exploring empirical relationships of damages with flood variables. This section develops methods for modelling flood damage potentials to properties in the residential and commercial sectors. The commercial sectors comprise the business and industries sectors. The same model used in modelling losses in the industry sector may be applied to losses in the business sector.

2.4.1 Method of Achieving 'Potential' Damages

Direct Damage

The models set out in the subsequent sections for assessing flood loss potentials all involve, first generating total potential damages from the damages that have occurred in actual events.

In this thesis the term 'potential damage' is used to denote the total likely damage, which could have occurred had the victims not adopted any measures to avoid this.

Inevitably, at some cost property owners often take some measures or actions to protect their properties before, during or after the event. Actual damages, which is indeed a component of the full potential damage, are not expected to portray strong 'functional' relationships with flood variables such as depths or durations. This is because the responses to a hazard are likely to vary greatly among property owners[13]. It is therefore appropriate to seek the relationship of 'total potential' damages with flood variables (e.g. depths and durations).

So, the principle of modelling damages concerns first estimating the total potential damages at some given depth or duration. The principal steps for achieving direct damage potential from actual damages are shown in Figure 2.2.

As illustrated in Figure 2.2, estimating the direct potential losses involves the following five steps:

a) Assessing actual losses
b) Assessing value of items at risk
c) Value of susceptible items that were protected or removed
d) Probable damages if the items are not removed; via proportion of actual damages occurred to the exposed items, and the susceptibility of the protected items
e) Damages avoided through protection or removal (net of expenses, if any)

Consequently, the total potential damages are expected to be higher than, or equal to, the actual damages. Thus,

Potential damages = Actual damages + Damages avoided by any action
Where,
Damages avoided = Damages that could have occurred in the absence of the measures undertaken minus cost incurred in the process of measures.

The first principle is to objectively assess the actual losses (with respect to the reference

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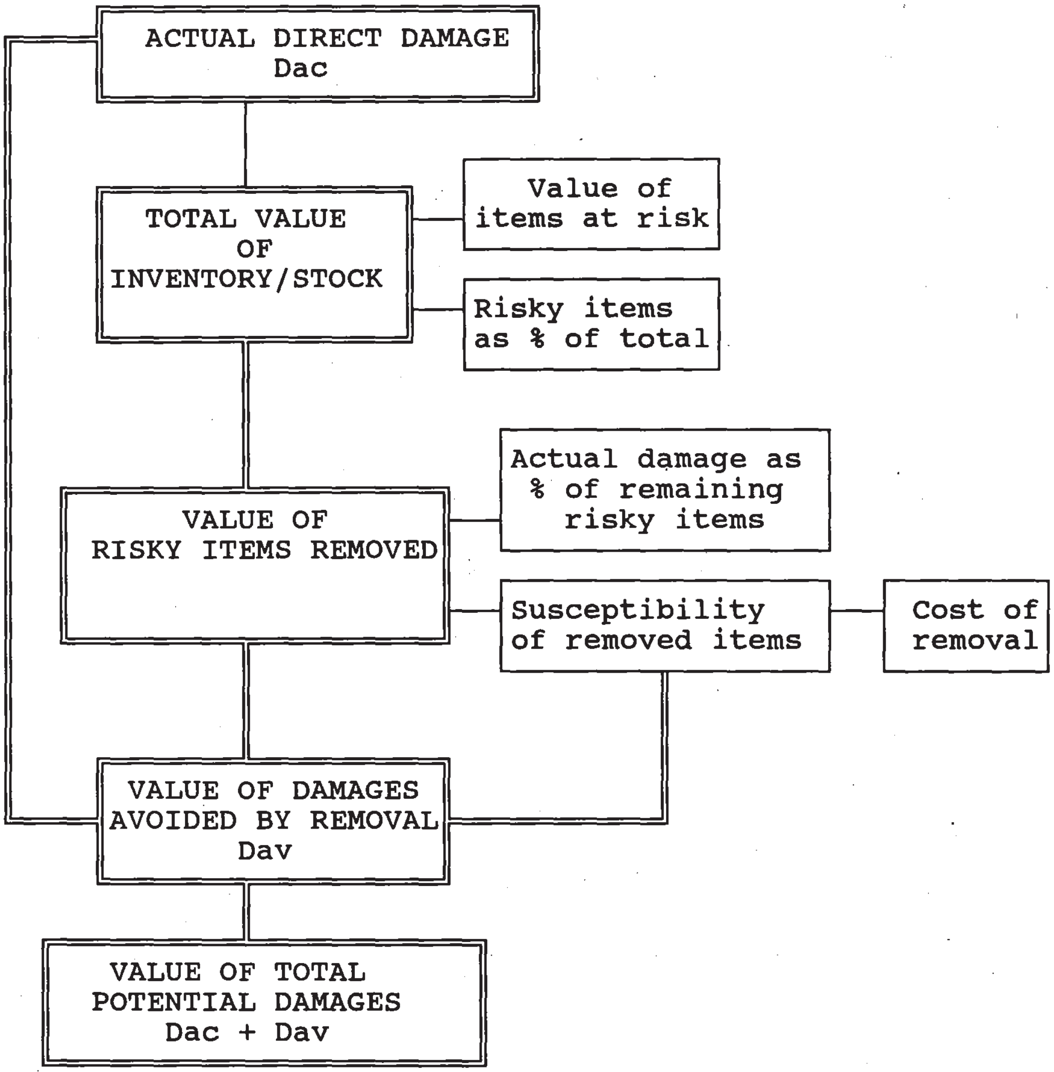
[13] This is particularly true in Bangladesh where floods have a long 'flood-to-peak' interval

Figure 2.2: Principal methodology for estimation of direct damage potential (from actual damage) to inventories and stock



flood), and then estimate total potential damages based on that. The second principle concerns making estimates, in relation to the actual losses, of the potential damages for some hypothetical flood scenarios, using the flood experience of the floodplain occupants[14]. In modelling damages at some disaggregated levels of depths and durations, the methods set out in the subsequent sections employ the potential damages for actual scenarios in combination with those at hypothetical scenarios.

Indirect Loss

The principal steps for the estimation of indirect losses in commercial sectors (business and industries) are shown in Figure 2.3. In the research the production loss in industries amounts to the loss to value added, and the turnover loss in business amounts to the loss to gross margin (Parker et al 1987).

Enterprises both within and beyond a floodplain may be disrupted by flooding. The principles set out here are for the assessment of losses to flooded enterprises. Total indirect losses are estimated as the sum of losses caused during complete closure and that caused during partial closure. The losses caused during partial closures amount to that of the normal output/turnover had there been no floods, net of recoveries during the period. The additional costs of working less efficiently, if any, are added to estimate the firm's total indirect loss. Like the principle of direct loss assessments, the methods set out employ the damages at actual scenarios in combination with those at hypothetical scenarios.

2.4.2 Total Loss Model

One of the primary aims of the study is to construct 'average' data sets for the main case study area (river flood) from field level estimates on damages. With this end in view, three flood loss estimation models are constructed, which are shown in Figures 2.4 through to 2.6. The basic structures of the three models are identical. They employ a combination of the 'unit-loss' method, the Cobb-Douglas model, multiple regression and the input-output model. The models, developed for modelling total loss, consist of three major components, e.g. for evaluating 1) direct loss 2) primary indirect loss and 3) multiplier effects. The direct loss component of the model is applicable to both residential and commercial sectors, while the

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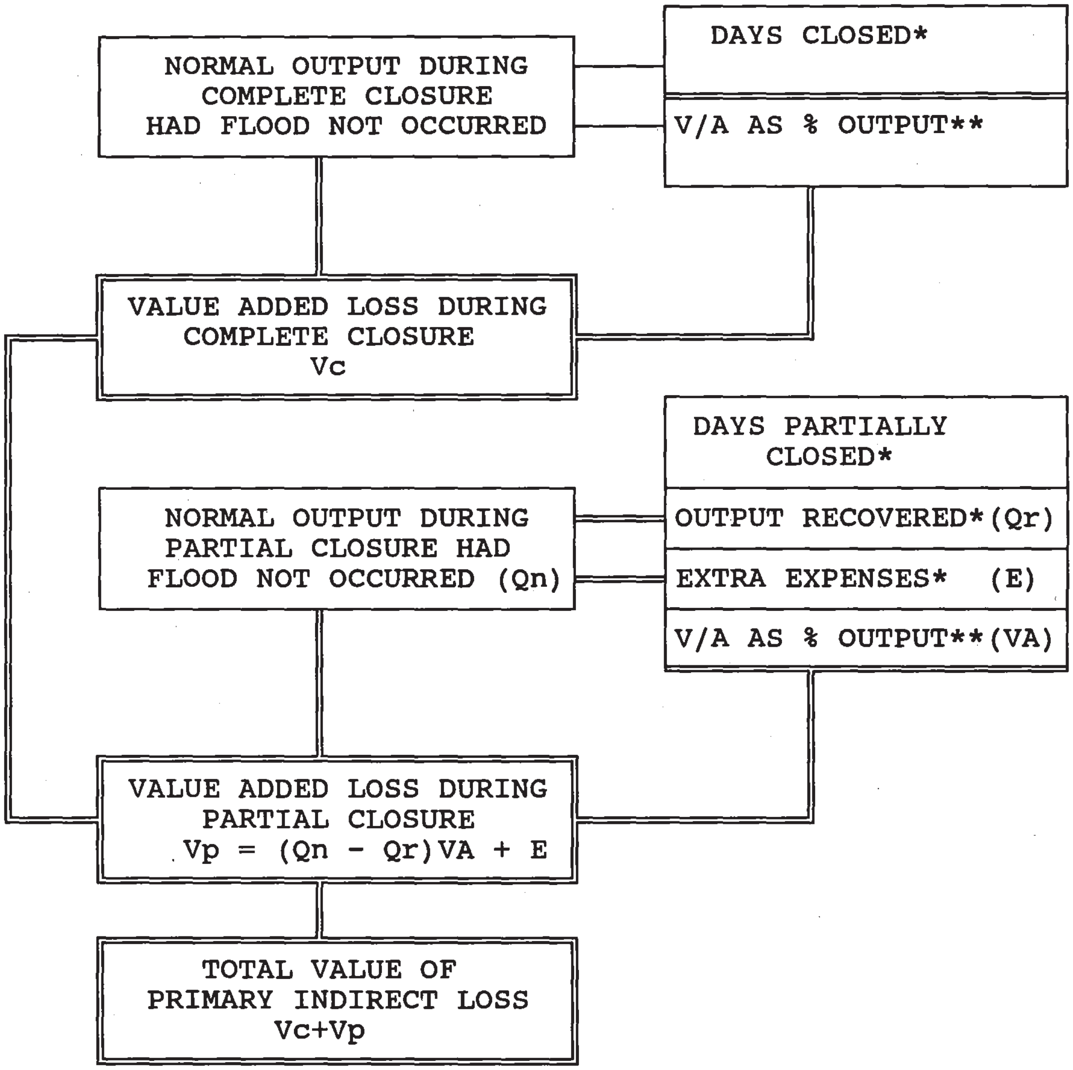
[14] The four flood scenarios are shown in Table C1 in Appendix C.

Figure 2.3: Principal steps for estimation of indirect loss from flood disruption in commercial sector



* From site survey
** From secondary sources/field survey
V/A = Value added

For business enterprises, Output is replaced by Turnover, and Value added is replaced by Gross margin

Figure 2.4: Flood loss (Total loss) model: Model 1

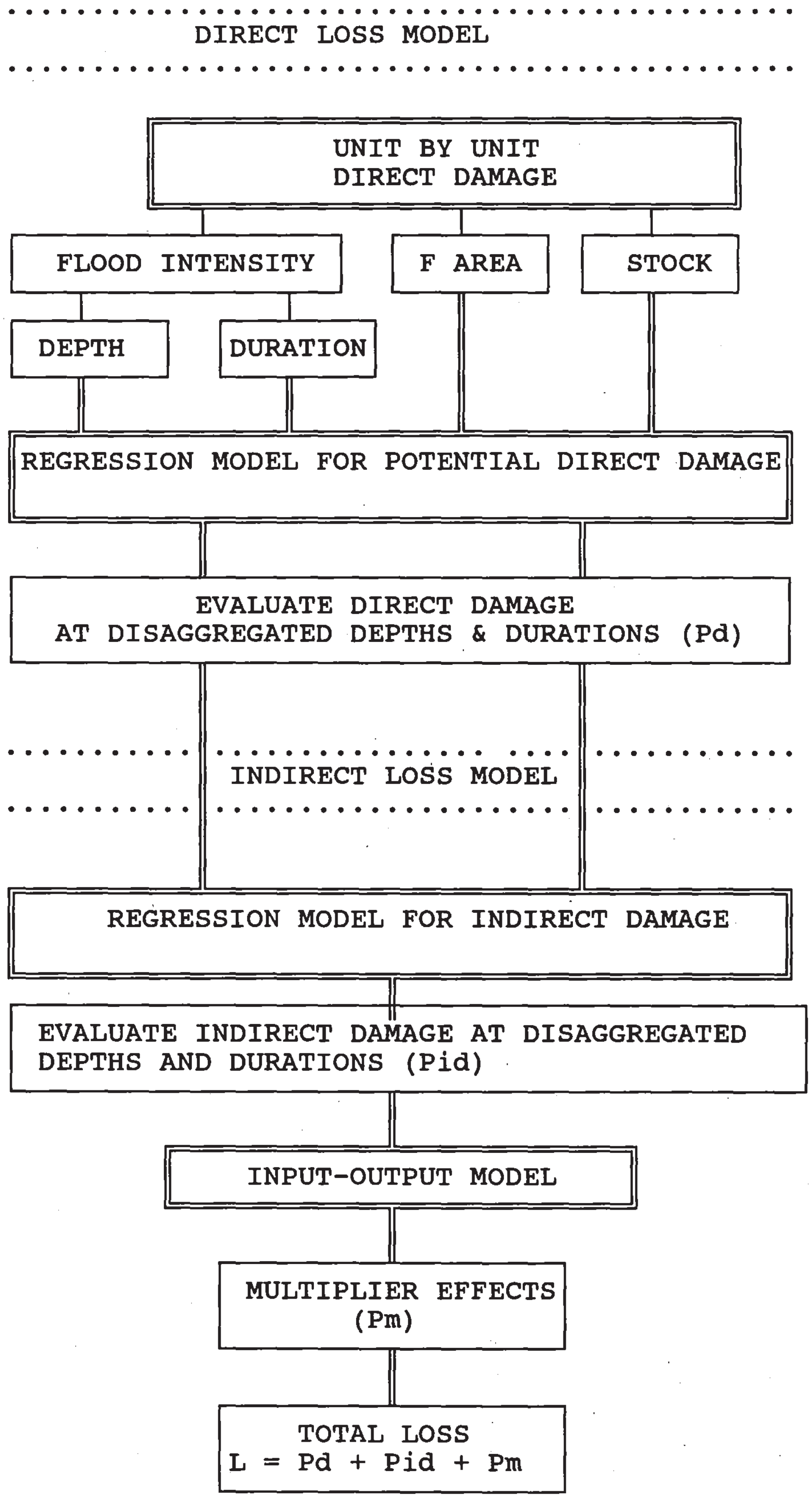


Figure 2.5: Flood loss (Total loss) model : Model 2

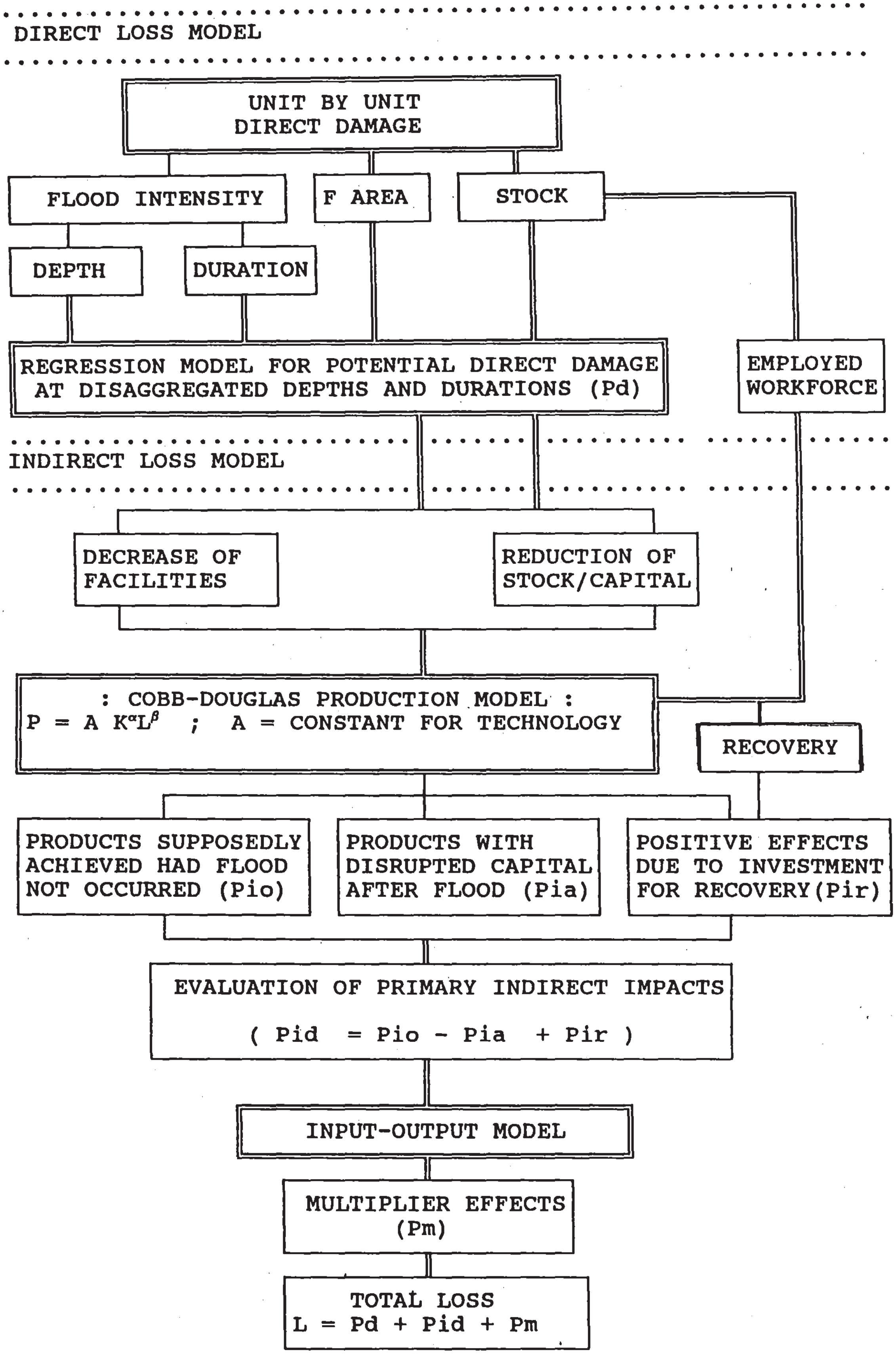
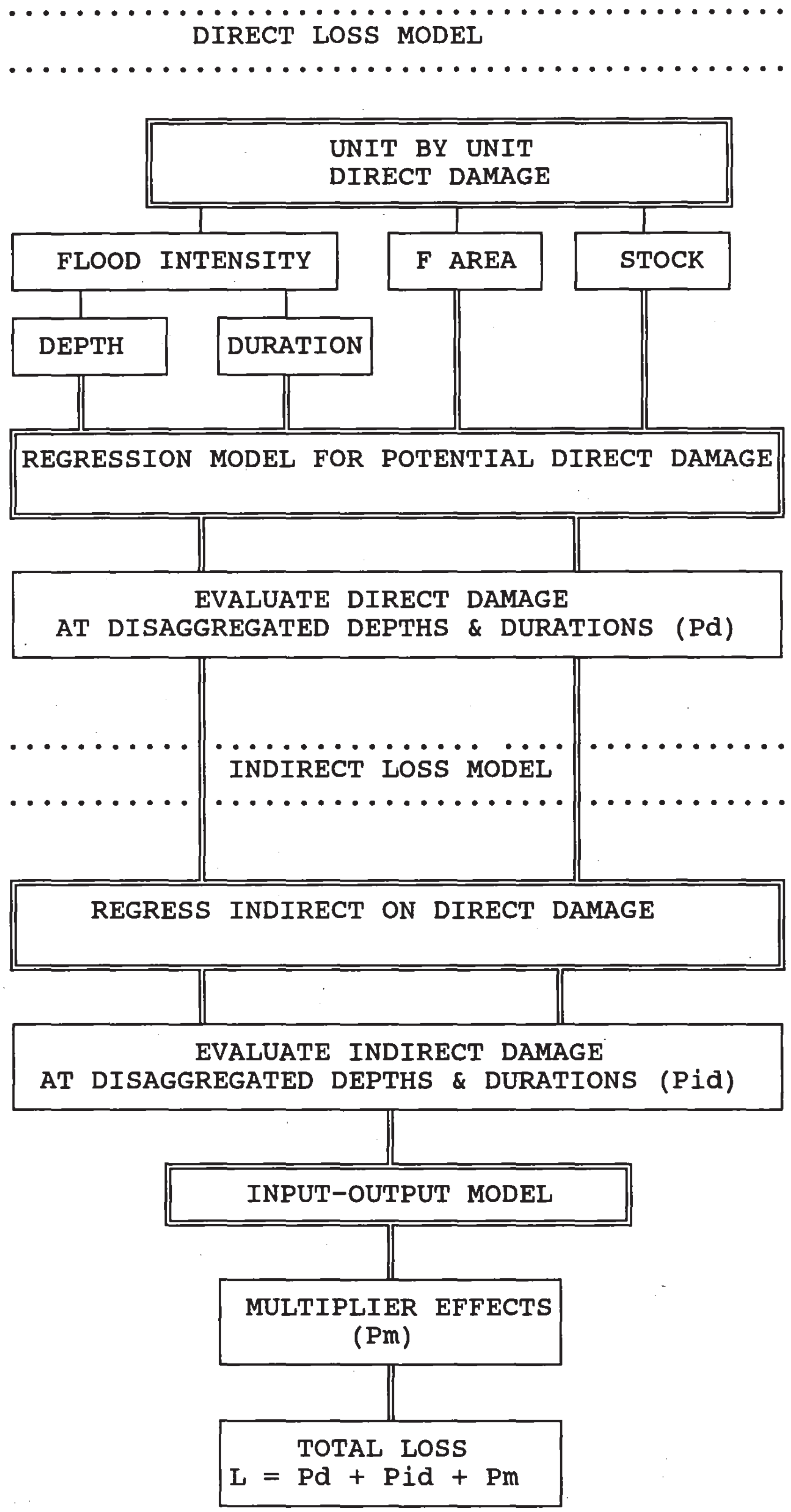


Figure 2.6: Flood loss (Total loss) model : Model 3



indirect loss component comprising primary indirect and multipliers, is applicable to commercial sectors.

2.4.3 Direct Loss Model

The physical direct losses are determined mainly by flood intensity. As the construction of damage data sets concerns a river flood with a moderate velocity, the present analysis considers depths and durations as the indices of flood intensity. Nevertheless, even with the same flood intensity, damages are expected to significantly vary following variations in the prevailing stock, type and quality of assets, and area of premises. Thus, stock of assets and area of space are considered two other explanatory variables in the model. The two variables may reasonably be incorporated through performing property groupings, as uniform as possible, according to their type so that within - group variations are minimum. The asset values and areas of premises are implicitly included when appropriate groupings are achieved.

The direct loss model uses multiple regression analysis to estimate the individual property damages by various damage components (e.g. structure, machinery/equipment and stock (input and output)) at disaggregated levels of depths and durations. The model can use either absolute or proportional damages to regress on explanatory variables.

2.4.4 Indirect Loss Model

The indirect losses, caused as a consequence of direct losses, eventually diffuse as short or long run effects to areas beyond firm, regional or national boundaries. As mentioned above the model considers the impacts of the flooded enterprises only.

The indirect loss model has two components: the model for evaluating primary indirect impacts and that for assessing multiplier effects. The primary indirect impacts, which are actually the indirect impacts of the first order, can directly be assessed like the direct ones.

Modelling of primary indirect impacts in the commercial sectors broadly considers three different methods (1) contemplating functional relationships on depths and durations (Figure 2.4) (2) the Cobb-Douglas production model (Figure 2.5) and (3) regressing indirect on direct damages (Figure 2.6). The models are applied to both industrial and business enterprises.

(1) Functional relationships with depths and durations

The first model is relatively straightforward (Figure 2.4). The estimated indirect damages in actual events, in combination with those at hypothetical events (as assessed through direct interview shown in Figure 2.3), are potentially related to flood intensity. The multiple regression model, regressing on flood intensity (depths and durations) and other variables, is used to subsequently yield the estimates of potential damages at disaggregated level of depths and durations for various major types of properties.

(2) The Cobb-Douglas Model

The second model is shown in Figure 2.5. The model is based on the Cobb-Douglas production function. The function is named after its two American originators, Charles Cobb (a mathematician) and Paul Douglas (an economist), who pioneered research in the area of applied economic growth in the 1920s and 1930s[15]. The Cobb-Douglas production function is of the form:

$$P_t = A_t K_t^{\alpha} L_t^{\beta} \quad (\text{ or, } \operatorname{Log} P_t = \operatorname{Log} A_t + \alpha \operatorname{Log} K_t + \beta \operatorname{Log} L_t)$$

where P = Output

A = Constant for technology

K = Capital stock, L = Input for labour and t = time.

α is the partial elasticity (responsiveness) of output with respect to capital (holding labour constant), and β is the partial elasticity of output with respect to labour (holding capital constant). Normally, α and β are less than unity on the assumption of diminishing marginal productivity so that $\alpha, \beta > 0$, and $0 < \alpha + \beta < 2$. The sum of the partial coefficients gives the scale of returns. $\alpha + \beta = 1$ represents constant returns, $\alpha + \beta > 1$ represents increasing returns and $\alpha + \beta < 1$ represents decreasing returns. Following that output, capital and labour input are known at time t (before flood) from enterprise level data, the parameters A, α and β are to be estimated empirically. Once the function is estimated for a before-flood situation, primary losses to output caused due to flood can be estimated

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[15] C Cobb and P Douglas (1928). A Theory of Production, **American Economic Review**, supplement, March

through imputing disrupted (reduced) capital and labour into the function.

The primary indirect losses associated with a flood are but the decrease of products, which are primarily due to the direct effect of the following two factors:

a) decrease of products, due to damage to physical (e.g. building, machines) and functional facilities (transportation /utilities)
b) decrease of products, due to damage to stock (e.g. input, finished products)

A reduction factor δK_i for capital is the proportion of the decrease of capital of i-th industry (due to flood) to the original capital before flood had taken place, that is

$\delta K_i = \Delta K_i / K_{io}$
where, δK_i = reduction factor
ΔK_i = decrease of capital
K_{io} = original capital

The reduction factors are estimated for different capital components (e.g. for building and machinery as fixed capital; for input and output as working capital); the reduction factors for total capital are estimated at individual firm levels. The reduction factors are applied to the estimated Cobb-Douglas production function in order to determine the decrease of production.

With regards to labour the broad assumption is that there will be insignificant effect on the total employment due to death and/or injuries, so that input for labour is assumed to remain unchanged.

The primary indirect losses for i_{th} enterprise associated with a flood are thus evaluated as

$P_{id} = P_{io} - P_{ia}$

where P_{id} = decrease of products/turnover by i-th enterprise
P_{io} = production/turnover supposedly achieved by i-th enterprise if flood had not taken place (with original capital i.e. before-flood situation)
P_{ia} = production/turnover achieved by i-th enterprise after flood had taken place (with disrupted capital i.e. after-flood situation)

The positive effect due to investment for restoration at the firm level is difficult to assess. However, repair and restoration after a flood will inevitably increase expenditures on the purchase of some materials, and this is indirectly reflected in the recovery of output/turnover of the affected enterprises after the flood event. The recoveries are incorporated while estimating the net losses during the field interview.

The procedure is applied to business enterprises replacing production by turnover, and the reduction factors estimated.

(3) Regressing on direct impacts

The third indirect loss model is shown in Figure 2.6 (Model 3). The Model uses the direct losses (modelled by direct loss model), as inputs to assess indirect losses by regressing on the direct losses. The procedure can be extended to a model where proportions of direct to indirect damages, instead of absolute damages, are used in the analysis.

Limitations of Approaches

The models discussed in the preceding section suffer from some flaws. The primary indirect losses estimated from the Cobb Douglas production model are the losses suffered at a point of time immediately after the flood, that is, when no activities are yet undertaken to restart enterprises (i.e. during complete closures). The loss at that point of time is the maximum loss occurred, which persists until the production is restarted. With the start of the units again, the losses start to be partially recovered until such time that the unit is brought to complete normality. An average recovery rate is to be incorporated to estimate the total loss during this recovery period. There are two limitations to this approach; one is that the flat recovery rate is likely to cause some amount of error in the estimation. The other limitation is that not all elements of the fixed capital are equally important in the production process. Some machinery and equipments, for example, are crucially important in the process and some may be only supportive. But the indirect loss models (particularly the Cobb-Douglas model) consider equal weight to the production process, uniformly and proportionately distributed.

Another limitation of the Cobb-Douglas model relates to the use of constant labour input. In a river flood, employment loss due to any loss of life may be ignored. Following floods, however, the affected enterprises might reduce the size of employment during both complete and partial closures. This is particularly relevant for those units which are run more by casual and temporary workers, the proportion of which in Bangladesh is considerable.

2.4.5 Modelling Multiplier Effects

Modelling of secondary and higher-round impacts (i.e. multiplier effects) is much more complex following multi-dimensional linkages among various sectors in an economy. This can, however, be best encountered through input-output analysis.

Input-output Models

The input-output analysis is a technique which employs a combination of mathematics (advanced matrix algebra, in particular) and economics to serve as a powerful analytical tool. The analysis is based on a table in the form of a matrix, called the input-output table, where the rows show the distribution of output to various sectors/industries and uses, while the columns show the distribution of their inputs needed for production. From the transaction matrix the effect of change in output due to flood losses on an economy can be resolved.

Assumptions

As is the case with most countries, even with many of the advanced economies, the input-output tables at regional levels are not available for Bangladesh. The present research therefore uses the national input-output table for estimating multiplier effects in the main case study town, which is available latest for 1986-87. Although the table is not updated as of now, even then the existing coefficients can safely be used based on certain broad assumptions, as is usually done in many countries, including advanced economies.

One of the broad assumptions is that there has not been any significant change in technology and pattern of trade since the updating of the Table (1986-87). This assumption is reasonable in the context of a developing economy such as Bangladesh, where there is little reason to believe that the technology and input-mix in industries, or the pattern of trades have changed significantly over recent years. The other assumption is that the national input coefficients can be applied to enterprises of industries at regional levels such as the main case study town, which typically represents industries at medium, small and cottage level.

Finally, it is assumed that the elasticity between inputs is unity so that the value of the coefficients will remain more or less unchanged, irrespective of changes in prices. Hence, the conversion of the coefficients to constant prices is not considered in the analysis.

2.4.6 Procedure of Modelling Multiplier Effects

The procedure of modelling multiplier effects through input-output model is described below. The input-output table of an economy, showing flows among various sectors of the economy, is broadly divided into four quadrants: two quadrants (e.g. processing and payment sectors) arranged horizontally, and two quadrants (e.g. intermediate users and final users) vertically. A schematic layout, in a simplified form, is shown in Table 2.3. The first quadrant, Q(A), shows flows of goods and services which are both produced and consumed in the process of current production; these are usually referred to as Inter-industry Flows or Intermediate Demand. The second quadrant, Q(B), shows various elements of Final Demand for output of producing sectors. The third quadrant, Q(C), provides what are called Factor Payments to the producing sectors, and the fourth quadrant, Q(D), shows the Primary Inputs which go directly to Final Demand sectors. The present research is concerned with quadrant Q(A) and quadrant Q(B).

In the producing sector, the Xs stand for the value of output, and the two subscripts denote the origin sub-sector and its destination sub-sector respectively. Generalising, X_{ij} are sales by industry *i* to industry *j*, or inputs into industry j from industry i, where i = 1,2...n and j = 1,2...n. The disposal of outputs to final users can be represented in exactly the same way. Thus, in the productions quadrant of the table, each row shows how the output of each industry is disposed of, and each column shows the origin of input into each sector. The sum of each row gives the total demand for each industry's output. In the payment sector, each item denotes value added of the industries concerned.

In the intermediate users sector, the sum of the columns gives the value of total output of each industry i.e. the sum of the value of inputs in the production sector plus the sum of value added in the sector. Thus the columns in the intermediate sector and the rows in the processing sector both add up to the total value of domestic production. Taken on the whole table, the sum of each row is the total demand, which equals the total sum of each row, the total supply. Thus, the total demand X_i, is the sum of each rows:

Table 2.3: Broad layout of an input-output table

PURCHASED BY SECTORS ⇒ ⇒	INTERMEDIATE USERS	FINAL USERS	TOTAL DEMAND
SALES BY SECTORS ⇓ ⇓	Industries uses - Q(A)	Consumptions Investments and Exports - Q(B)	
Productions	(n x n) matrix	(n x m) matrix	
1	X_{11} X_{12}... X_{1n}	F_{11} F_{12}... F_{1m}	X_1
2	X_{21} X_{22}... X_{2n}	F_{21} F_{22}... F_{2m}	X_2
.	....	....	.
.	....	....	.
n	X_{n1} X_{n2} ...X_{nn}	F_{n1} X_{n2} ...F_{nm}	X_n
PAYMENTS	Wages,Rents,Profits and Imports - Q(C)	- Q(D)	
	(p x n) matrix	(p x m) matrix	
1	P_{11} P_{12} ... P_{1n}	I_{11} I_{12} ... I_{1m}	
2	P_{21} P_{22} ... P_{2n}	I_{21} I_{22} ... I_{2m}	
.	....	....	
.	....	....	
n	P_{p1} P_{p2} ... P_{pn}	I_{p1} I_{p2} ... I_{pm}	
TOTAL SUPPLY	X_1 X_2 ... X_n		

$$X_i = \sum_j X_{ij} + F_i \qquad (1)$$

Similarly, the total supply X_j is the sum of each column, which is as follows:

$$X_j = \sum_i X_{ij} + P_j \qquad (2)$$

The major concern of this research is the inter-industry transaction matrix, which is the primary instrument to assess multiplier effects. For the purpose of the assessment, the input coefficients for each of the producing sectors are required. The input co-efficients are derived by dividing each column entry in the matrix by sum of the column. Thus, the input coefficients, a_{ij} is given by

$$a_{ij} = X_{ij}/Xj \qquad (3)$$

$$\text{or, } X_{ij} = a_{ij}Xj. \qquad (4)$$

In other words, the input coefficient a_{ij} gives the amount of purchases from each industry to support one unit of output of industry j. Thus, the equation 1 can be rewritten from equation 4 as

$$X_i = \sum_{j=1} a_{ij}Xj + F_i \qquad (5)$$

$$\text{Or, } X_i - \sum_{j=1} a_{ij}Xj = F_i \qquad (6)$$

which may be expressed more compactly as

$$\mathbf{X} - \mathbf{AX} = \mathbf{F} \qquad (7)$$

where,

$$\mathbf{X} = \begin{pmatrix} x_1 \\ x_2 \\ \\ . \\ . \\ x_n \end{pmatrix} \qquad \mathbf{A} = \begin{pmatrix} a_{11}\ a_{12} \ldots a_{1n} \\ a_{21}\ a_{22} \ldots a_{2n} \\ \\ . \quad . \quad . \\ . \quad . \quad . \\ a_{n1}\ a_{n2} \ldots a_{nn} \end{pmatrix}$$

$$\text{and } \mathbf{F} = \begin{pmatrix} F_1 \\ F_2 \\ \\ . \\ . \\ F_n \end{pmatrix}$$

The equation (6) for all industries, $i = 1,2 \ldots n$, is a system of n simultaneous equations in n unknown variables which are solved by appropriate matrix algebra[16]. From equation (7), it can be derived

$\mathbf{X} - \mathbf{AX} = \mathbf{F}$

Or, $(\mathbf{I} - \mathbf{A})\mathbf{X} = \mathbf{F}$

where, $(\mathbf{I} - \mathbf{A})$ is called the coefficient matrix.

The set of equations are solved for X as

$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}$

where, $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief Inverse matrix[17], and **F** is the Final Demand vector.

Now, for normal non-flood period, **X**, **A** and **F** are known; after flood, however, **F** will change to $\mathbf{F_a} = \mathbf{F} - \mathbf{P_{ia}}$, where $\mathbf{P_{ia}}$ is the primary loss vector, already assessed by indirect loss model. The analysis then seeks to assess the new reduced X, consistent with newly derived reduced amount available for final users, known as Final Demand, $\mathbf{F_a}$.

In other words, each industry's output is equal to the final demand vector (which is a column vector of order n x 1) times the coefficients of the inverse matrix $(\mathbf{I} - \mathbf{A})$. The outputs of all industries, thus, will have to be consistent with final demand for the products of all industries. The ultimate change in output must equal the sum of the direct and indirect effects of the change in final demand.

Hence, following a change in final demand due to floods as a primary effect, the change in each sector's output can be estimated. The first decrease of final demand is equal to the decrease caused by the primary indirect effect. The second round effects on production in each sector are then given by the input-output coefficients. The third-round effects are given by the derived (declined) demands in the second round multiplied by the input-output coefficients, and so on.

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[16] The process in solving the equations first involve inverting the coefficient matrix. The inversion of the matrix involves deriving the co-factor matrix and then transposing it, which is divided by the determinant.

[17] The term Leontief is due to Professor Wassily Leontief, who introduced Input-output analysis in the early 1920s.

2.4.7 Limitations of the Approach

The analysis has some limitations. A set of assumptions are adopted for the assessments to be valid. The assumptions are as follows:

1) The final demand vector is affected only by the primary production loss; that is, the quantity available for final users is equal to the quantity net of losses in production.

2) The final demand vector is to ignore the ripple effects. That is, it is to assume that the net effects of income losses (and hence decline in effective demand for products), on one hand, and income rises (hence rise in demand for products) due to recovery activities, on the other, are reflected in the overall fall in production.

3) This analysis is likely to be constrained by the type of floods, as in the event of wide-spread flooding, the economic structure relating to export to, and import from, the rest of the economy (i.e. from outside the town) is likely to change the demand vector.

The problem of new levels of final demand can be confronted in other ways. During the field investigations, the entrepreneurs both of industries and businesses, were asked what they felt about the potential change in demand for their individual products in their town in the post-flood situation. Although most entrepreneurs reported decline in demand, some business units dealing in such products as related to restoration, reported otherwise. Such data on changes in demand compared to pre-flood situation for individual enterprises may be incorporated towards achieving the estimates of net changes in final demand.

A more detailed discussion on the limitations of the analysis is made in Chapter 5 while assessing multiplier effects of primary losses in sample industrial enterprises (Section 5.1.6).

2.5 Summary

In aggregate, research on flood hazard in general and flood losses in particular is relatively recent and carried out mainly in a few advanced countries. In Bangladesh, there exists almost no basic research on flood losses and their assessment methods, especially for urban or non-agricultural losses. Flood loss assessments involve many assumptions and estimation procedures. No universally accepted methods have yet emerged. Over the recent time, the researchers in the UK, centred mainly in the Flood Hazard Research Centre, have made a breakthrough in the field of flood loss modelling in both residential and commercial sectors.

Assessment of flood loss potentials in the residential sector, based upon actual events are found to be impracticable for many reasons. In consequence, researches in the countries such as UK, USA and Australia largely adopted the synthetic approach in the assessment of flood loss potential in the residential sector. Unlike in the residential sector, the assessment of flood loss potentials in the commercial sector are largely based on interviews with management personnel.

With regards to regional loss models, two models are largely in use, the regional econometric model and the unit-loss model. The regional econometric model is generally used in earthquake impact modelling, and the unit-loss model in flood loss modelling. The regional econometric model generally uses I-O tables to determine the effects on the total economy. It is argued that the regional econometric model is more appropriate for large-scale events but constrained by scarce time series data on a large number of socio-economic variables. The unit-loss model incorporating unit by unit damage by flood levels has its capacity in producing 'fine-level estimates' for damages, disaggregated over depths, durations, sectors and impact types. The model is capable of appraising benefits for a range of standard of protection, through frequency analysis based on mathematical probabilities. Thus, despite that the model is demanding in terms of data, the unit-loss model is more suitable to flood loss modelling in Bangladesh.

Given the likelihood that damages are related to flood intensities (e.g. depth, duration) and other variables (e.g. floor space), the present research seeks to model flood losses based on surveys of actual flood events through exploring empirical relationships. The models set out for modelling total losses (consisting of three model components: direct, primary indirect and multiplier effects), employ a combination of the 'unit-loss' method, the Cobb-Douglas model, multiple regression and the input-output model.

CHAPTER 3: THE STUDY METHODOLOGY

3.1 Introduction

This Chapter explains how the study is implemented, and includes discussion of the research boundaries, research design and limitations. Sampling techniques and sample size determination approached are presented in Appendix B. The principles of measurements of flood variables and data limitations are presented in Appendix C.

3.2 Research Focus

Contemporary flood researches have concentrated mostly on direct impacts. The modelling of linkage effects has not been adequately addressed. Following this, the research seeks to examine the role of indirect effects in total impacts in commercial sectors. Hence, the study focuses more on indirect impacts, including the linkage effects in commercial sectors. In the residential sector, the study focuses on direct impacts. Assessment of indirect impacts in this sector are beset with the problem of double counting with the commercial sector.

3.3 Boundaries of the Research

Field research, which encompasses loss data generation, is itself a major component of the research. In order to comprehensively appraise the benefits of urban flood protection (i.e. costs of flooding), what is required is a complete and exhaustive set of loss data covering all the related sectors and impacts which necessitates undertaking a very large study. Given that an urban flood study entails study of a large domain of sectors, and wide range of impacts and their assessment methods, and given limited endowments in terms of material and time, this study should be viewed as a 'case demonstration'[18] of research on flood impacts. Hence, the present investigation is to be conceived in the framework of certain set boundaries, which are discussed below.

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[18] However, the methodology for constructing a nationally applicable data set and aspects such as sample size determination are discussed in Appendix B.

3.3.1 Research Coverage of Sectors

In essence, urban impacts and non-agricultural impacts of flooding in Bangladesh are analogous (Figure 3.1). Contemplation of urban impacts covers almost all non-agricultural impacts that are also relevant to rural losses. Conversely, if non-agricultural losses in rural areas are considered, the major sector of industries, (especially the large and medium-sized ones), which are localised mostly in urban areas, is excluded. Additionally, traders also largely operate in urban areas. So, all non-agricultural impacts in rural areas are also urban impacts, but not all the urban impacts are non-agricultural impacts in rural areas. However, the agriculture sector, which is relevant to rural areas, has been adequately addressed in Bangladesh in terms of flood research. In aggregate, the present investigation entails urban non-agricultural impacts which, by analogy, also embodies rural non-agricultural impacts (Figure 3.2). The following five broad sectors, which, are viewed as comprising the main urban loss sectors, are investigated :

1) Residential
2) Business (Trading)
3) Manufacturing
4) Office and Public buildings
5) Roads

3.3.2 Type of Impacts

The study investigates direct and indirect impacts, albeit only the tangible ones. These are impacts to which a monetary value can be assigned. The intangible losses, that cannot usually be directly measured in terms of money (e.g. environmental goods, health stress and human losses), are excluded, whether or not these be direct or consequential. Although urban areas may contain fewer agricultural activities, the present study has not been able to include the study of the agricultural losses. The concentration of the investigation on the sectors and the impact types should not, however, suggest that the other sectors or impacts are overlooked or considered unimportant.

3.3.3 Methods of Assessment

With a view to carrying out the study within a manageable boundary, the research does not attempt to generate fine and detailed level standard loss data sets. Given that there can be

Figure 3.1: Major sectors under flood risks in urban and rural economies and concern of the study

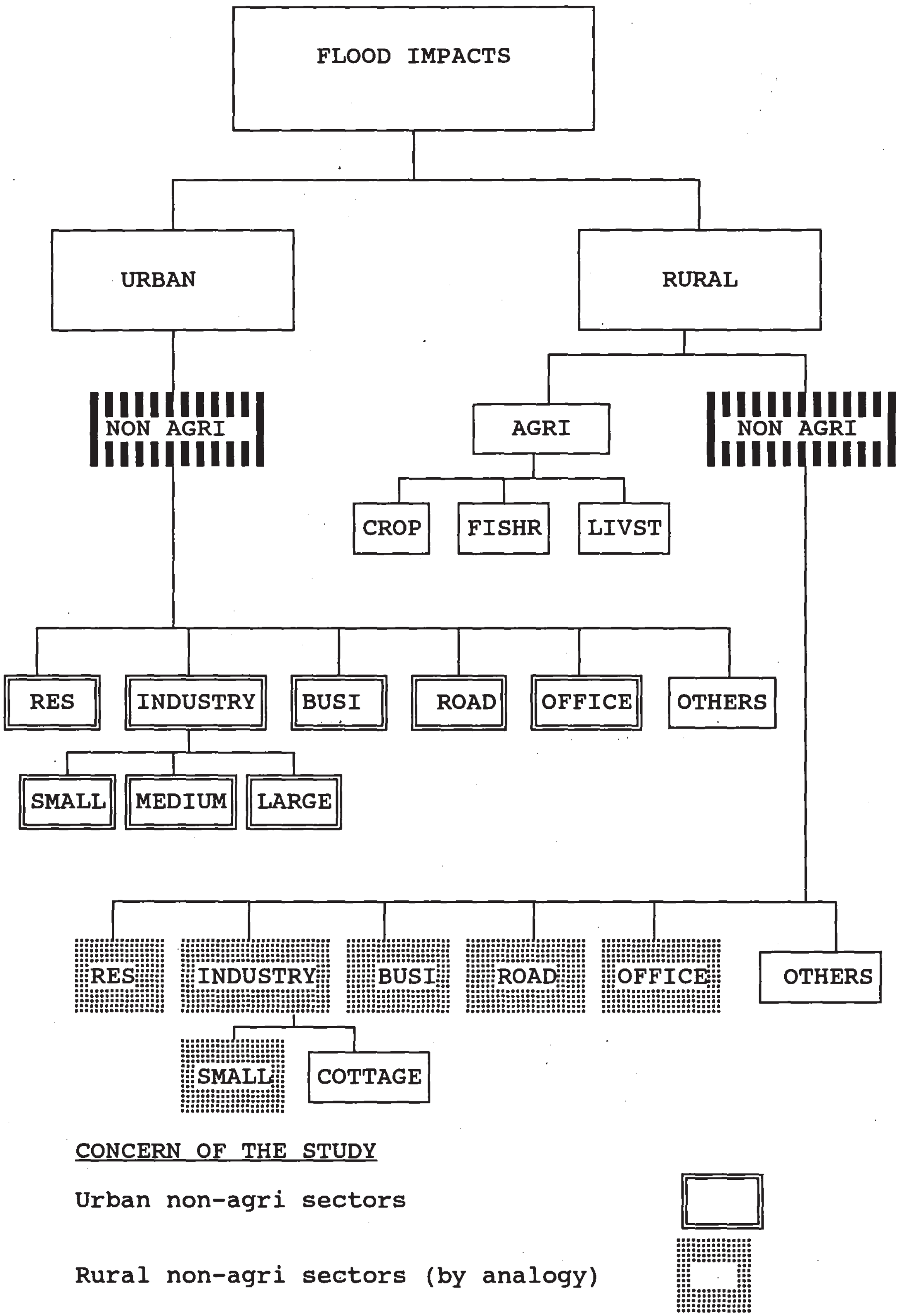

Figure 3.2: Research coverage on broad sectors

Sector	Agriculture	Non-agriculture
Urban	Do not usually exist	**Focus of the present study**
Rural	Already adequately studied	**By analogy**

a wide range of methods and alternative approaches to flood loss assessments suiting various requirements and situations, which, again, generally largely depend on the levels of details in the data availability, the study seeks to devise those methods which are suitable for rapid and intermediate scale appraisals. Like Rapid Rural Appraisal (RRA) principles (discussed later in this chapter), which are conventionally 'rapid' but 'dirty', the present research seeks appraisal methods that might not be much refined, but which are rapid and cost minimising (a sort of 'intermediate/appropriate technology'). This feature is crucially important for countries like Bangladesh. With the availability of fine-level loss and land use data, however, the methods can be extended for use in 'full' project appraisals. The assessment methods, including the generated loss data sets, apply largely to the river flood under study.

3.3.4 Land Use, Land Level and Hydrological Data

A detailed land use, land level and height survey is undertaken as, this is a *sine qua non* for yielding benefit assessments. However, detailed level hydraulic and hydrological components are beyond the boundary of this research. For a fine level appraisal, frequency analysis for both flood stage and flood discharge is important. The detailed-level discharge data before the installation of a scheme is imperative for applying mathematical models to simulate stage-discharge, probability-discharge, stage-damage and finally loss-probability relationships. This analysis has not been pursued in such details; in this research the frequency analysis is based on flood stage. This is not just because this component relates to hydrology and engineering, but because this is one of the areas in which Bangladesh (and many developed countries, including, perhaps, UK) has scarce records, for most urban locations.

3.3.5 Benefit-cost Analysis

Although benefit-cost analysis is the ultimate aim of any project appraisal, such analysis is not within the purview of the present research. Nonetheless, some approximate estimates of costs for a few standards of protection are calculated, which facilitate a preliminary comparison with the benefits of protection.

3.4 Three Reference Floods

The research uses three reference floods: a river flood, a flash flood and a tidal flood. The following is a brief description of the three floods under investigation.

3.4.1 The 1988 River Flood

Between late August and late September 1988 Bangladesh was hit by a flood worst on record. Nearly two-thirds of the country's area was inundated by the flood; of the country's 64 districts, 52 were under water for about a month. Almost half the total population (47 million) were directly affected by the flood. Widespread damages were caused to crops, infrastructures, houses and properties (see Table 1.6 for the extent of damage). An expected frequency (return period) of once in 40-100 years (depending on locations) has been suggested as a measure of severity of the flood. In contrast to the 1987 flood, which was largely generated internally, the 1988 flood was viewed to have been caused by heavy precipitation in the upper catchments outside the national boundary, combined with the simultaneous attainments of peak levels of the big rivers. Particularly the three international rivers, the Brahmaputra, the Padma and the Meghna were in a flood stage several weeks before. Unusually the flood peaks of the Brahmaputra (the highest level ever recorded) and the Padma coincided. As a result, the entire floodplain of the Padma, the Brahmaputra and the Meghna river systems of the country, including most of the towns and cities, were inundated. More than two-thirds of the Dhaka (capital) city, with its 7 million inhabitants, was under water for more than three weeks. More than 2500 Km of flood embankments were totally damaged by the flood (Table 1.6).

3.4.2 The 1993 Flash Flood

The north-eastern region of Bangladesh situated at the foot hills of Khasia-Jaintia and Tripura hills' range is an area vulnerable to flash floods. An approximate area of 5200 sq km (4 per cent of the country's area) comprising three river basins is vulnerable to flash floods. The three basins are Brahmaputra basin, Meghna basin and Muhuri-Matamuuri basin, of which the Meghna basin is the most vulnerable, consisting of 63% of the total flash flood area (Wajed 1986). The Habiganj district, which is situated in the Meghna basin, is particularly prone to flash floods.

The 1993 flash flood was a local flood affecting a number of Thanas in the Habiganj district, including Bahubal Thana[19]. Bahubal is situated in the confluence of Khoai and Karangi

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[19] Thana is an administrative unit under a District, which is the main unit of local government.

river. In the two months period during May-June (1993), three flash floods hit the Thana, said to have caused as result of combined effect of incessant rains in the hilly areas and a breach at the river embankment of the Khoai river. The breach on the embankment, was widely reported as man-made, and executed by the upper-stream inhabitants of Habiganj town, which was under tremendous threat from inundation at that time. The flood lasting for two to four days caused extensive damage to crops, houses and properties.

3.4.3 The 1991 Tidal Surge

The coastal areas of Bangladesh consist of large estuaries, tidal flats and low-lying islands in the vicinity of the Bay of Bengal. Tidal surges from the sea generated by tropical cyclones are the source of widespread damage to lives and properties. On the night of 29 April, 1991 one of the country's most severe tidal surges hit the coastal areas of Bangladesh. The storm surge of 4 to 9 metres height lasted for about 6-8 hours depending on locations (Figure 3.3). Vast areas in the districts of Cox's Bazar, Chittagong, Noakhali, Lakshmipur, Patuakhali and Bhola were devastated. At least 10 Thanas were severely affected. The maximum sustained wind velocity varied between 225 to 235 km per hour (65 metres per second) (Haider et al 1991). The night (29 April 1991), which is termed as 'Doomsday', has seen devastations unprecedented in the recent memory in Bangladesh. It claimed about 150,000 human lives, besides causing colossal damages to infrastructure and properties (Table 1.7).

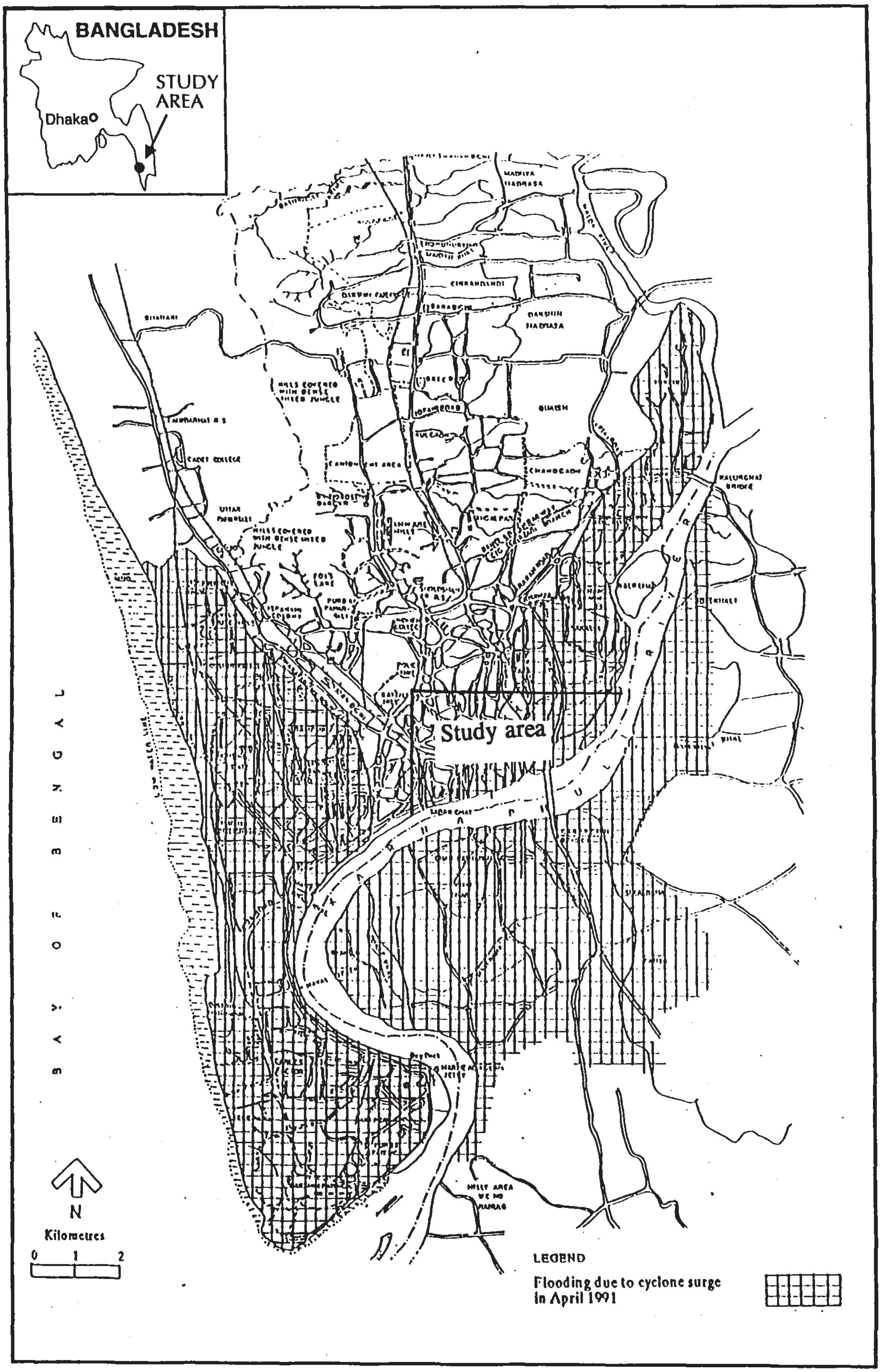
3.5 Study Design

The construction of an appropriate research design is important in that it acts as a guide towards how efficiently the study is implemented and the research methods adopted in the process of collecting, analysing and interpreting observations, keeping in mind the research questions. A wide range of research methods is available to hazard researchers, and hence a brief discussion on such methods is in order.

3.5.1 Research Methods

Socio-economic studies involve data collection in either formal or informal settings, which, eventually involve either verbal or nonverbal responses. Broadly four types of methods of investigation are in practice: Observational methods, Survey methods, Secondary data analysis and Qualitative research methods (Frankfort-Nachmias and Nachmias 1992).

Figure: 3.3
Flooded areas: April 1991 tidal surge



The observational methods involve collecting information directly through understanding, realising and predicting from what exists, as a direct observant. The Survey methods involve collecting data on those phenomena that are not directly accessible, and which can only be obtained through personal interviews. The Secondary data analysis method is a method of collecting data through consulting existing published and unpublished documents. Qualitative research methods, more often employing case study methods, involve the detailed investigation of a relatively few subjects adopting observational methods, in general, and participant-observational methods, in particular.

To a certain degree, research findings are affected by the nature of data collection methods used and thus different research problems call for different methods. However, no method is foolproof; each of the data collection methods has certain advantages and disadvantages. The main advantage of the observational methods is its directness of data collection. But not all phenomena may be readily available for a researcher to directly observe. The study of behaviours and activities of floodplain occupants during a flood event, for example, requires one to wait for a flood to occur which is not often possible. In many such cases, it may be more feasible for a researcher to approach a sample of individuals having some relevant experiences and, based on such experiences, obtain responses through interviews.

The survey method is one of the data collection methods more frequently used in socio-economic studies. Among the survey methods, the direct interview method is often suitable. High response rates, an opportunity to probe and a control over the method are often among the advantages. Interviewer bias, however, is one the main limitations of this method. Secondary data analyses can be the only source available to certain research problems. It may also be used for comparative purposes. Besides being cheap and easy to collect, this method is useful for the longitudinal research.

Thus the major two data collection methods are the survey method and the case study method, briefly discussed in the following section.

3.5.2 Case Study Approach and Survey Method

There can be various research strategies in social science research: experiments, surveys, case studies and histories. Each strategy has its merits and demerits. In general, a case study approach is adopted when 'how and why questions are posed' (Yin 1989). The case study approach, as opposed to a traditional survey method, is an approach by which an investigation is carried out on a pre-determined number of cases, selected not on the basis of sampling techniques but rather purposively. The approach, like experiments, is 'generalizable to theoretical propositions and not to populations or universes'. In this sense, the case study approach, like experiments, does not represent a 'sample', and the investigator's goal is to expand and generalise theories (analytical generalisation) rather than to enumerate frequencies (statistical generalisation) (Yin 1989). This approach is, however, often seriously criticised as being unable to provide generalisation due to 'lack of representativeness'. The criticism stems mainly from the 'misconception that a case study is as if it is a sample of one drawn from a wider universe of such cases' (Bryman 1988). The survey method, on the other hand, is an appropriate means of gathering information under three conditions: when the goals of the research 'call for quantitative data', when the information sought is reasonably 'specific and familiar' to the respondents, and when the researcher himself/herself has considerable 'prior knowledge of particular problems and the range of responses likely to emerge' (Warwick and Lininger 1975, as quoted by Bryman 1988).

Some researchers (e.g. Van Maaneen et al 1982) treat qualitative research and case study research as synonymous. However, evidence depicts that within its domain, a case study approach can be qualitative or quantitative, or even both in a particular research, depending on the characteristics which are being investigated. Some inquiries which cannot be captured by quantification through structured questionnaires, for example, are less difficult by exploratory and unstructured approach. This approach is particularly useful when there is no theory or concept before the investigator to prove or disprove.

One of the most important criticisms against the survey methods (and in support of the case study approach) is that researchers can hardly stick to randomness or representativeness while selecting sample. Because of many problematic situations, investigators often resort to a restricted or purposive sampling technique. Although a large majority of researchers (e.g. Bryman 1988) mention that data gathered from quantitative survey studies are 'often depicted as hard, rigorous and reliable', to some qualitative researchers such data are superficial.

In aggregate, the research approach to be adopted depends on a host of factors, such as the nature of investigation (whether exploratory, reconnaissance or rigorous), relationship between theory and the research, and the scope of findings ('*nomothetic* approach - seeking to establish general laws irrespective of time and place, or *ideographic* approach-locating its findings in specific time, periods and locales' (Bryman 1988).

3.5.3 The Present Study Approach

The present research is a quantitative empirical research of flood impacts providing little scope for direct observation or participant observation. However, secondary and historical analysis are employed in the analysis of flood impacts at the macro level. The research has an explicit research design to link the data to be collected with the study's initial questions, and, ultimately, with the conclusions to be drawn. The crucial issues of the investigation are 'what', 'where', 'when' and 'how much' to observe and record.

An approach of investigations mainly depends on the initial questions of the study posed. Since the study concerning flood loss quantities ('what' and 'how much', in particular) aims at achieving scientific inferences (especially in regards to the testing of a set of hypotheses), some statistical analysis are essential. Towards achieving this end, the research adopts the survey method, which resorts to some sort of representative sampling. However, the research seeks some qualitative information, in order to reveal, understand and explore a wide range of effects. For example, the investigation on impacts contains qualitative aspects such as health, stress, perceptions and adjustments, a substantial part of which are qualitative in nature containing open ended queries. While some case studies on households and enterprises are carried out to get some detailed insights in relation to such variables that cannot be captured through structured set of enquiries, some information in the form of field observation are supplemented with the in-depth interviewing method.

Although the current data collection procedure is essentially based on survey methods, the investigations are confined within a few case study towns. One of the towns is taken as a case study area for demonstrating appraisal methods.

3.5.4 Types of Survey Methods

Broadly three types of survey methods are commonly in use: Mail questionnaire method, Interview method and Telephone interviewing method.

The mail questionnaire method is an 'impersonal' survey method. The major advantages are the low cost and easy accessibility. Among the shortcomings, low response rates and the lack of opportunity for probing are important. The low response rates are, to some extent, overcome through follow-up mailings and improvements to the questionnaire formats.

The Interview method comprises face-to-face interviewing through structured and unstructured questionnaires. The former is commonly used in quantitative analysis, where designed questions with a fixed sequence are asked to obtain answers pertinent to the research hypotheses. The latter interview method is the non-directive interviews having no structured set of questions to ask.

Telephone interviewing is a substitute for personal interviewing. The major advantages of the method are the easy accessibility and convenience of random sample selection. The method is frequently cost effective, gaining wide applications in advanced countries where the telephone communication network is highly developed and telephone ownerships and literacy rates are high. However, the method is seldom used in developing countries, as the telephone ownerships and literacy rates are miserably low. The mail questionnaire method has also seen limited applications in such countries for similar reasons. In developing countries situations, the interview method is found to be more effective in that the interviewees can properly be approached (in a business-like pleasant manner) and convinced through personal interactions by explaining the objectives of the survey[20]. The research thus employs a face-to-face interview method, administered through mainly structured questions.

3.5.5 Rapid Rural Appraisal (RRA)

Rapid Rural Appraisal (RRA) principles, developed over the recent time (since the late 1970s), have seen considerable applications in the evaluations and appraisals of water development projects. One of the uses of RRA is to carry out a rapid assessment of pertinent issues in order to better design a detailed data collection process. The principles emerge 'as a strategy for an exploratory work where there are unknowns' (Moris and Copestake 1993). The broad principles, as opposed to traditional methods, involve methods of collecting data

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[20] This is particularly important, in the context of the present survey, through seeking cooperation from the respondents, as some initially emerged suspicious of the interviewers, taking them for representatives of the government. Personal interactions were helpful towards seeking cooperation from the victims, who remain generally stressed, especially immediately after floods.

that are cost effective and quick ('rapid' but 'dirty'). The quick methods are often useful in delivering necessary information to decision-makers in a timely or accessible way. The RRA method is in fact an 'intermediate technology', by means of which returns to a little effort spent on acquiring new information emerge as high, compared to returns to a lot of efforts on acquiring higher quality data, at much higher costs and resources. Thus the merits of RRA are well described while Moris and Copestake (1993) maintain that 'in the language of micro-economics, marginal returns to open enquiry are often greater than returns to more focused enquiry'. In Bangladesh, the RRA's 'rapid' and 'dirty' methods have widely been practised in the evaluation of completed water management projects over the recent past[21].

A wide range of techniques are available within the RRA methods of data collection. Group interview and key-informant interview techniques form the major tools of RRA; the use of expert judgment in some difficult issues is also often sought. 'Triangulation' is one of the major techniques, the concept of which is based on the fact that there are many different ways of looking at any project impacts. The principle involves obtaining information in a variety of ways and from as many as sources as possible, even for the same information. Stratification and randomisation of samples is a technique that helps ensure representativeness with a minimum bias. The RRA techniques also involve investigations by research teams with members from various disciplines. A pre-designed check list through which investigations are guided allow the team members carrying out open-ended interviews more productively. Short reports are produced on various aspects of field inspections. Sharing the field experience with fellow team members allows integration of the work of various professionals so that a group view of appraisals on different issues emerges.

The RRA methods are not, however, without flaws. The methods are critically described as 'Rural Development Tourism' by Chambers (1983) and other rural development experts in IDS, (Sussex University), for example. The most important weakness is that the methods suffer from a range of bias.

Among them the important ones are spatial, person, time and professional bias. Nevertheless, the biases are not difficult to encounter. Spatial bias can be overcome by investigating both heads and tails of a flood embankment, for example. Person bias can be

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[21] For example, FAP-12 (1992) carried out 17 RRA appraisals in the early 1990s, and BUP (1988) conducted RRA appraisals of some EIP projects in the late 1980s; the author was involved in these studies as a socio-economist (FAP-12 1992; Islam 1988).

confronted by including a wide range of informants in the investigation. Time bias is minimised by exploring conditions throughout the year while professional bias can be reduced by exchanging views among members of different disciplines.

The Present Research and RRA

The present research uses a combination of RRA and sample survey techniques. In order to better understand the issues related to flood losses and their assessments, the research undertakes a reconnaissance survey before the 'full' survey is carried out. The reconnaissance survey concerns obtaining information on, among others, prices of construction materials by quality and type, susceptibility of property components to water and prices and longevity of new and second hand household goods. A variety of RRA techniques is used for the purpose. Besides using secondary data sources, group interviews, key-informant interviews (e.g. with contractors and builders) and expert judgements (e.g. from structural engineers) are also sought.

Although the investigations are carried out at enterprise levels, some enquiries (e.g. qualitative information) require extra efforts involving other personnel, such as accountants, managers and key personnel in addition to the entrepreneurs. For example, it proves useful to seek responses on trends of the employment, income and price of commodities (during post-flood situations) from a group of people rather than from a single respondent. The reliability of data are enhanced by seeking information from more than one source, a technique of enquiry known as the 'triangulation'. For value of properties, for example, the responses are liable to a range of variations, for which a consensus is needed. Expert opinions are particularly helpful in this respect. The aspects such as perceptions on floods and warnings, threats to flood hazards and flood losses at hypothetical floods are at times better explored through group views. The views of knowledgable members in households and key personnel in commercial units prove frequently helpful in the data collection process of the current study.

The research employs an investigating team consisting of a structural engineer, a surveyor and professionals from social science. Daily report writing on what was observed and gathered through open-ended enquiries, including the exchange of views among the team members proved effective in capturing many flood loss information.

3.5.6 Data Collection as an 'Insider'

The research is carried out in a foreign country on the part of the researcher. The topic and field data, however, relates to the researcher's own country, and the investigations are carried out as a 'cultural insider'. There can be several advantages to research investigations as a 'cultural insider'.

Whatever the type of investigations, be it quantitative or qualitative, the data collection process involves the researcher first attaining some kind of partnership or 'close attachment' with the investigating subjects. Admittedly, setting the environment, formal or informal, in the situations being observed is *sine qua non* to a meaningful data collection. Familiarity of the principal investigator and others with the native language and culture can play a major role in effective and efficient investigation. An investigator from his/her own society can have adequate control over the process of data collection, and thus the approach to the respondents is more practical-oriented. Davis (1981) recognises the dangers of cultural detachment which are faced by research workers from western advanced countries working in the Third World. These researchers often fail to grasp the realities of local cultures and are 'too ready to project western values' (Chan 1995).

In any socio-economic survey, there is always some information that is difficult to capture by interviewing through structured questions. Understanding the respondents properly, preparing case reports, and capturing informal observations through field notes is likely to be more fruitful in the investigators' own native language. Particularly in flood research, some impacts may easily be observed, especially when the victims are stressed. Some impacts, on the other hand, may well be better investigated than are observed. For either type of the data, finding the truth is important. The aspects relating to an appropriate time of interviews, a longer stay with the community, proper approaches and judgements, local practice of measurements are some of the merits of being an 'insider'. This is more so in case of qualitative data (e.g. response to floods and adjustment mechanism), the collecting methods which involve more 'observational methods' in rather close environments. An insider familiar with local environments has the advantageous situations in evaluating an informant's subjective report of what s/he feels or thinks about some subjects under investigation. The present research, albeit to a limited scale, has also been involved in collecting such data and information. Experience suggests that the reactions of the respondents to being interviewed or observed tend to be rather critical in the case of a stranger rather than a member of the same community. Given the cultural and religious values, women respondents, in particular, are less accessible to a stranger, even of the same society, let alone to a foreigner.

The familiarity and deep understanding of the Bangladeshi culture and society is thus a methodological strength of the present research. The strength is enhanced in that the investigation is carried out by the author, not just as a member of the Bangladeshi society but also as a researcher in a leading research institute, having a long data collecting experience (about 20 years, often in unfavourable and strange situations)[22]. This research experience is vital, especially in getting access to rare documents of the government and other organisations, including the Water Board and the Bureau of Statistics[23]. Besides, had the author no earlier experience of data collection, it could be difficult to obtain such demanding estimates of flood losses, staying for longer than six months in relatively remote study areas[24].

Being an insider investigator, however, also has flaws. Perhaps the most common demerit is the 'cultural blindness' embodied in an investigation. Since the investigators have already had the feel of the area, community and people, the investigations could turn out with some 'blindness' of own pre-conceived ideas. In such cases, it could be possible that some most common phenomenon might not seem discernable and thus could be evaded or oversighted. In consequence, some sort of bias may occur. It may thus be an useful way of contemplating floods in a developing countries perspective, once one had studied that from other viewpoints and angles. The aspects discussed above, however, are borne in mind during the investigation. A full one year pre-survey training in the foreign country is fruitful in this respect. The existing flood researches carried out in the developed countries perspective are contemplated before the starting of the field survey. The questionnaires designed in such a foreign country, which is later pretested in the field of own country situations, has hopefully captured the wider perspective and overcome potential 'cultural blindness'.

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[22] The experience includes research involvement of the author in a recent study of Flood Action Plan (FAP).

[23] The Macro level analysis exclusively employs secondary data, collected from a multiple sources like Water Organisations and Bureau of Statistics.

[24] In one of the three main study areas, field work was carried out immediately after the flood. The cooperation of local officials particularly in this area was essential.

3.5.7 Selection of Case Study Areas

One of the important components of the study is to investigate differential impacts caused by different types of flood. Thus, three case study areas are selected to represent three different floods. As discussed earlier, the three floods are the 1988 catastrophic river flood, a flash flood occurred in 1993 and a tidal flood occurred in 1991. Incidentally, the three study areas fall in three of the six ecological regions of the country.

From among the 125 urban areas in Bangladesh, the main case study town is selected based on some criteria. That is, the town is:

a) essentially a flood prone area having a past flood history,
b) a town adequately representing the selected loss sectors,
c) of relatively small size, in terms of population, property and area so as to keep the study in a manageable form (in terms of, say, conducting the land use and level survey),
d) an area having relatively high concentration of industries and business
e) an area having hydraulic and hydrological information as much as possible,
f) not remote from the main survey office (Dhaka), to enable efficient operation in view of limited resources
g) not already, or planned to be, covered by Flood Action Plan (FAP) studies, in respect of town protection.

Taking into consideration of the above criteria, Tangail town is selected for the main case study area, which represents a river flood. Following a similar set of criteria the other two areas are selected. The two areas are Bahubal (Habiganj) for a flash flood, and Khatunganj (Chittagong) for a tidal flood.

3.5.8 Reconnaissance Survey

In order to gain an idea of the level and the type of properties, firstly, a reconnaissance survey in each of the study areas is conducted. The results of the survey were used to determine sampling techniques and sample size. Without going into details of the survey, only a brief description of three areas is presented, with special reference to the main case study area.

Area and Location

The locations of the three study areas are shown in Figures 3.4 through to 3.6. The main case study area, of Tangail town municipal area, has an approximate area of 32 sq km. It is situated by the river Lahajang, which is a branch stream of Dhaleswari river, the distributary of the Jamuna. The town is divided into 6 administrative divisions called wards. The second case study area (the case of flash flood) Bahubal, is a Thana headquarters situated under Habiganj District, the district which is frequently affected by flash flood. The Thana is situated in the confluence of Khoai and Karangi rivers. Although by definition the area is urban, it is characterised by a mixture of rural and urban economy. For much the same reason, the survey is confined in an area within a radius of 1.5 km from the headquarters. The third case study area, Khatunganj, is situated in the confluence of the river Karnafuly and the Bay of Bengal. Located at the south-east corner of Chittagong port city it is said to be second largest business centre in the country. A large number of medium and large-sized industries are located around the centre,. Khatunganj business centre has an approximate area of 1 sq km.

Flood Proneness

The past records available from the district BWDB office indicate that Tangail town was flooded seventeen times in the last three decades (1960-89), of which the recent four floods in 1980, 1984, 1987 and 1988 were most severe. Habiganj District is typically a flash flood area, but Bahubal is not that much. In 1993 the Thana was said to be flooded for the second time in the last decade. But during the year of investigation, the Thana was flooded two to three times depending upon locations. The township, Khatunganj, is not a severely (except in the 1991 tidal flood) and frequently flood hit area although it is a cyclone-prone area, located in the vicinity of the Karnafuly river and the Bay of Bengal.

Roads Network

Roads are the first-stage sampling units, by which the properties under investigation are situated. During the reconnaissance survey, a census of the main roads and streets (principal branch roads) were carried out. The census estimates that the Tangail municipal area contains more than 400 roads, comprising a total of 47 principal roads. In Bahubal, the Thana headquarters and its surroundings contain 40 roads and streets, of which 8 roads are

Figure: 3.4
Tangail Pourashava (Municipality):
main case study area

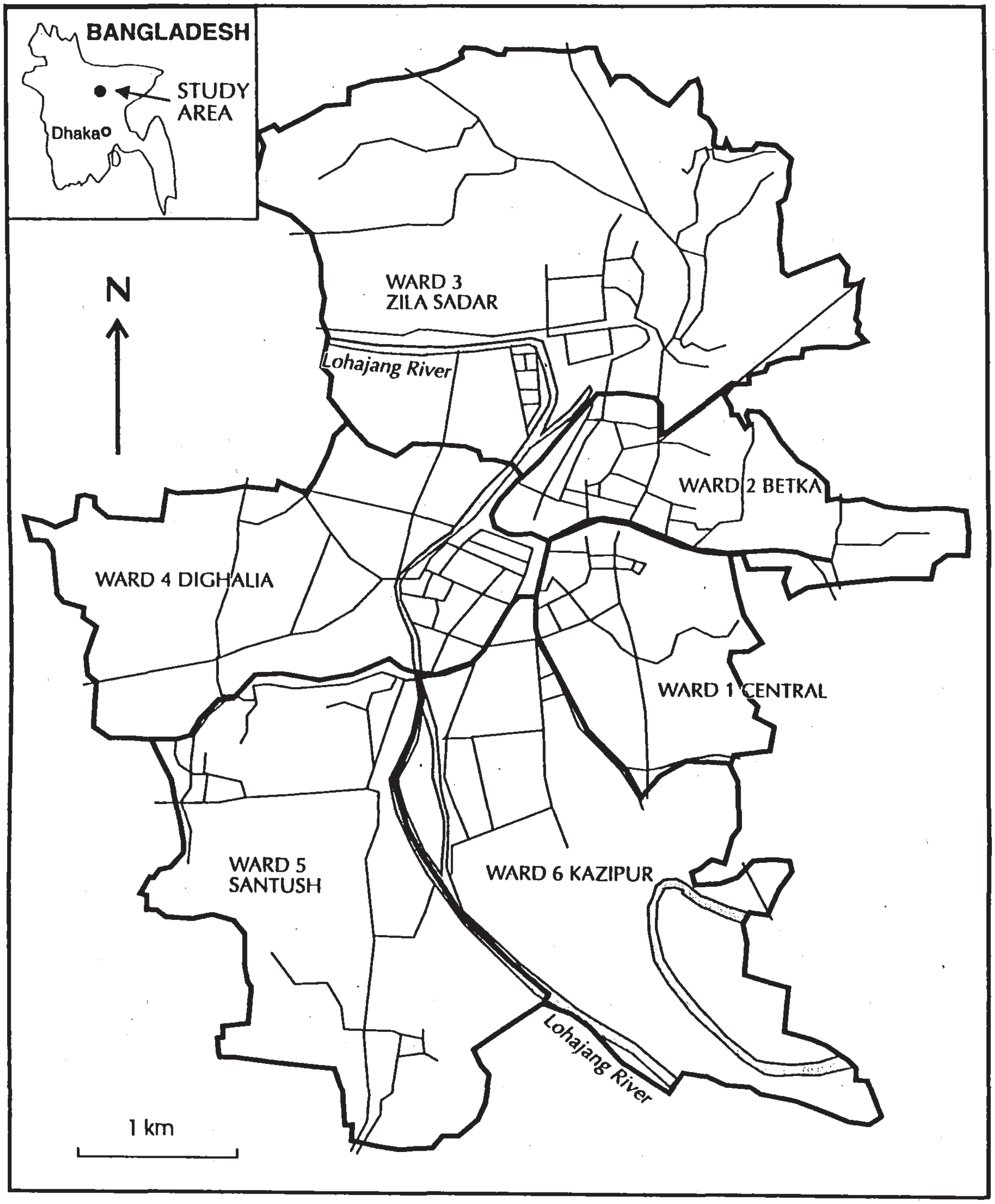


Figure: 3.5
Bahubal Thana (Flash flood study area)

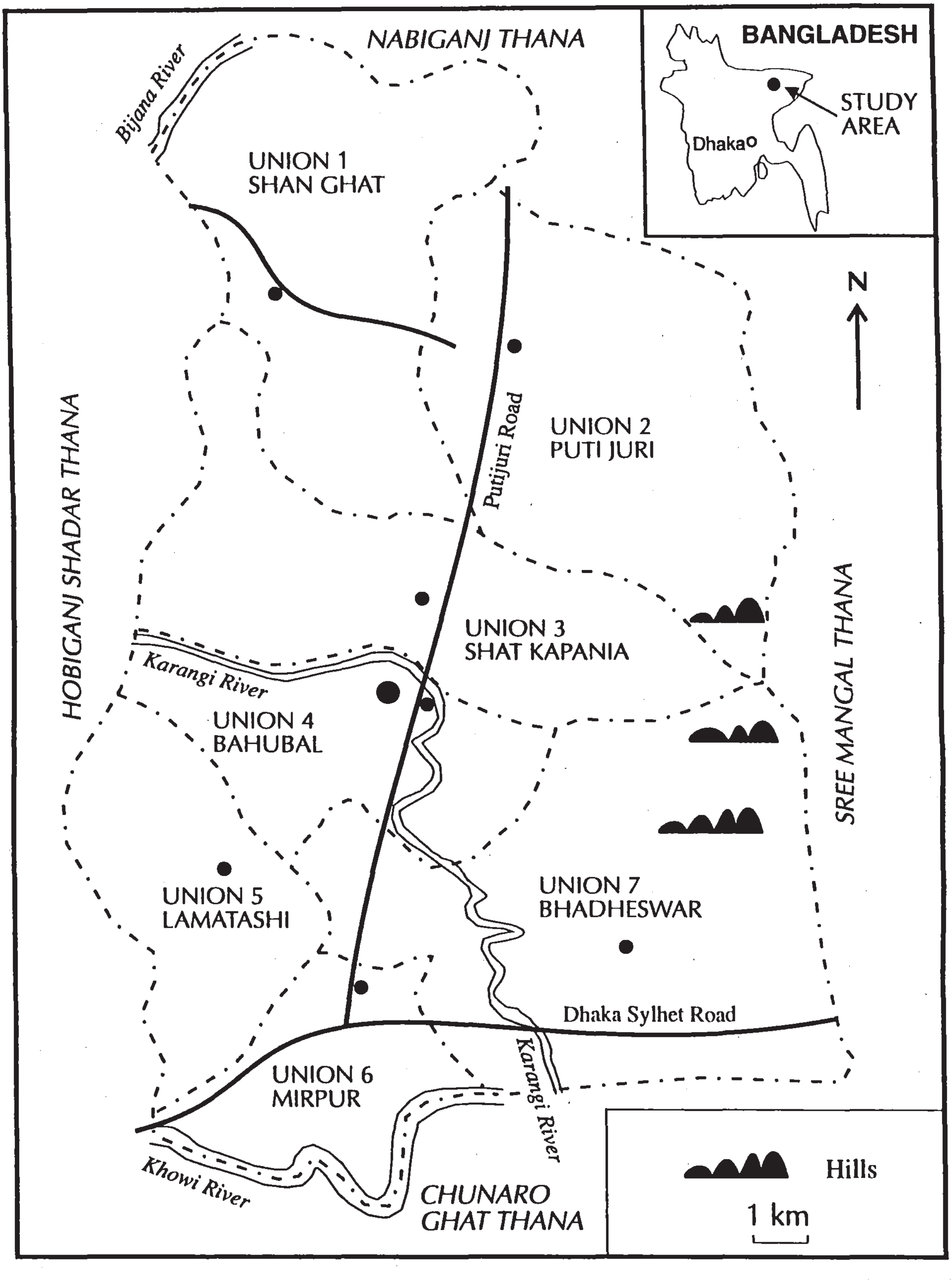
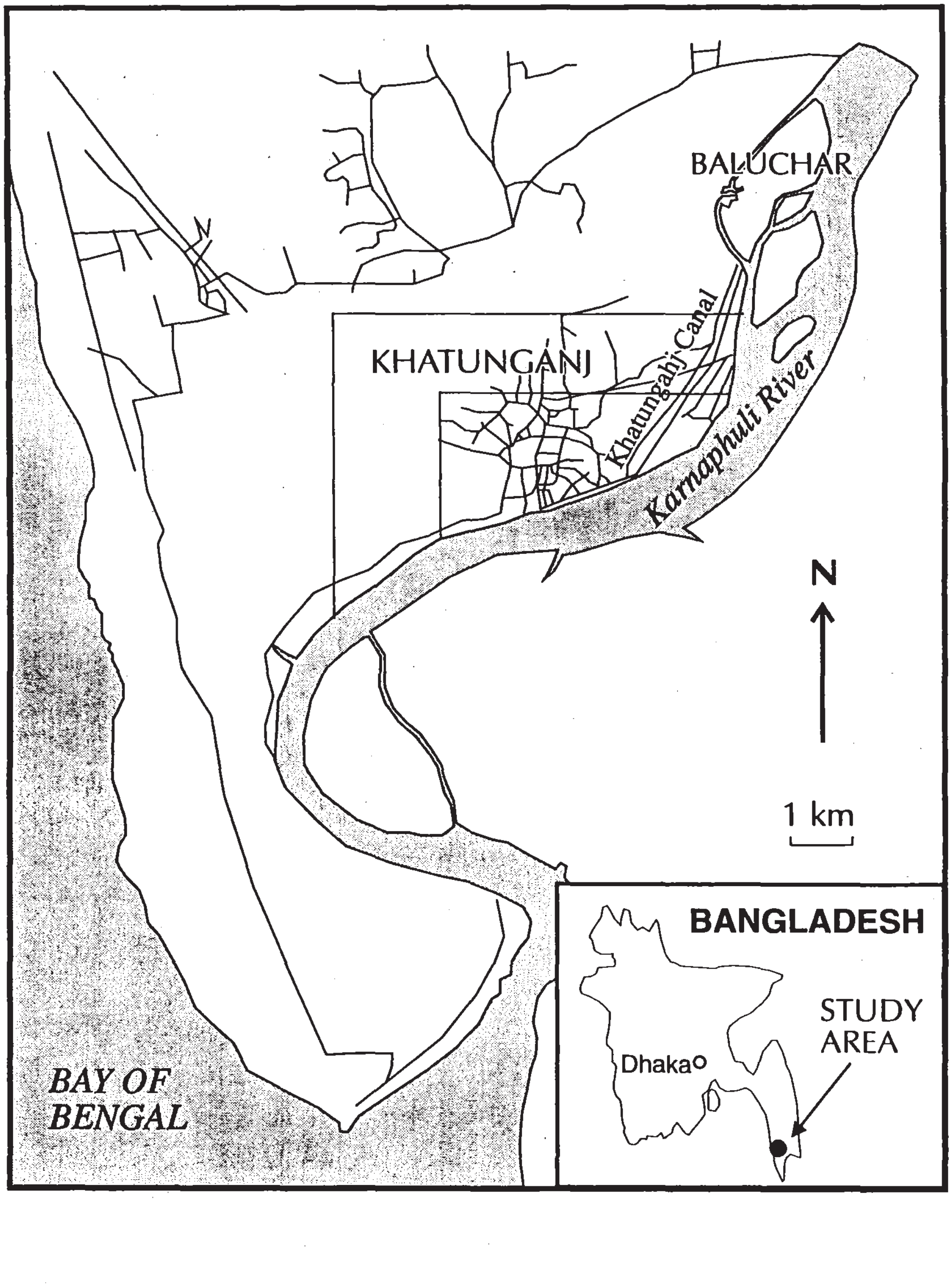


Figure: 3.6
Chittagong city map: tidal surge study area



identified as principal roads. The Khatunganj study location has as many as 80 distinct main and sub-roads, of which the number of main roads identified are 15.

Type of Properties

House Types

The selection of sample and the generation of potential damage data sets first involves arranging various properties into groups, as homogeneous as possible. Table 3.1 presents type of existing properties by groups in the study areas. According to construction materials used there are five main types of houses in the three case study areas. The house type M-M (mud floor and mud wall) is only found in the second case study area, Bahubal.

Business Activities

There are 55 types of business enterprises in the study areas at 4-digit level. The enterprises are grouped into 7 broad groups (shown in Table 3.1). A substantial proportion of shops are mobile and informal, having no fixed establishments or addresses, and operating in temporary structures. Such temporary structures are assumed to present insignificant potential damages, so these are not contemplated in the present analysis.

Industrial Activities

According to the Bangladesh Standard Industrial Classification (BSIC 1986), various industries in the country are grouped into 36 major industrial groups (3-digit level), which are again divided into 264 industrial sub-groups at 4-digit level. The reconnaissance survey (including from secondary sources, CMI, in particular) reveals that the study areas contain approximately 60 types of industrial activities at 4-digit level, which are grouped into 5 broad sub-sectors (Table 3.1).

3.5.9 Principles and Problems of Sampling

The sampling design for any research study depends primarily on the nature of the problem and the desired precision of the results. Heavily influenced by the availability of time and resources, the choice of techniques is also imposed by certain statistical and administrative

Table 3.1: Sectors and sub-sectors under investigation

House type

1 : Brick (floor), brick (wall) - BB
2 : Brick (floor), corrugated iron sheet (CI) wall - BC
3 : Mud (floor), CI sheet (wall) - MC
4 : Mud (floor), thatched, (wall) - MT
5 : Mud (floor), mud (wall) - MM

Business group

1 : Food and grocery
2 : Cloth & footwear
3 : Drugs & chemicals
4 : Electrical & electronics
5 : Motor/cycle parts
6 : Construction materials
7 : Miscellaneous

Industry group

1 : Food and agro-based
2 : Cotton and textiles
3 : Timber & furniture
4 : Engineering & electrical
5 : Miscellaneous & service

Office and Public building group

1 : Government office
2 : Utility office
3 : Hospital & clinics
4 : Educational & religious institutes
5 : NGOs & other private office

considerations. Additionally, the sampling techniques depend on the level, type and other characteristics of the population units under study. The approach to sampling techniques and sample size determination is discussed at length in Appendix B. Following that the basic principle of sampling procedures in the three study areas is the same, the procedure for the main case study area is discussed below.

3.5.10 Sampling for Households

The roads are the first stage sampling units, by which the properties are situated. First of all, in a bid to perform some sort of stratification, 12 main roads in the main case study area were randomly selected, taking 2 from each of the 6 Wards. From each of the roads, a total of 12 households (3 for each of the 4 category of houses) are selected. While selecting the roads, the criterion of hydrological variability is taken into account in order to include as many flood 'depths' and 'durations' as possible. The variations in depths and durations were ascertained from discussions with a cross section of local residents during the reconnaissance survey. The selection is done such that the selected roads are (a) located nearer to each other (to minimise cost of visits) and (b) not very long (to enable making a census of the houses quickly). Additionally, the selection is made such that the chosen roads are located, at places both near and off the main river that traversed the town. This is done to include larger variations in flood water levels[25].

Given mainly that the detailed sampling frame of the population is not available, a systematic sampling procedure is considered more appropriate for the selection of the households. Besides, the systematic sampling technique is administratively easier and quicker, which often yields higher precision than the simple random sampling. Such a technique has the additional advantage that the selected samples become spread over the population, following particularly that the households are scattered over a large contiguous area. However, in such sampling the order of the households is assumed to follow a random pattern. A quick census is conducted to prepare an approximate sampling frame for each of the roads. The selection procedure involves choosing every k-th subsequent unit after the first sample is chosen at random, where $k = N/n$, N = population size, n = sample size.

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[25] The selection of roads thus could not be fully restricted to random sampling procedure.

The procedure with a 'random start' is adopted for all the individual categories of houses, without replacement.

Limitations to Sample Selection

A set of alternative samples is also drawn for each type of houses, as the sampling procedure could not be strictly followed because of the following limitations:

a) The owner-occupied households, rather than tenant respondents, are to be preferred, to enable obtaining more precise estimates, especially in respect of the damage values,
b) For much the same reason, the household heads are to be preferred for the interview,
c) The households who, for some reason or other, were not present in the town at the time of flood are to be excluded,
d) If the type of the house selected had changed after the flood, there is no alternative but to omit the household,
e) The houses that have dual uses (e.g. residence-cum-business) are to be excluded, and
f) Non-responses/non-cooperations despite repeated visits.

The case of non-responses/non-cooperations is minimal in general, with the exception of a few cases in the flash flood area, who were very stressed and reluctant to respond. In the end, approximately one-fourth of the total selected households in the main case study area had to be excluded because of the above restrictions. In place of such cases the just adjacent households, or at the worse the next to them, are selected for interviews so that the randomness character is least affected.

3.5.11 Sampling for Business Units

By concentration of business in the study area, a list of important markets is first prepared. A notable feature of the business locations is that almost all of the prominent markets contains most of the existing activities listed, which eases the sample selection. The sampling procedure adopted for business and industrial enterprises is similar. For business, first, 5 important market places are selected, as dispersed as possible over the town. The markets are purposively chosen so that taken together they contain all the broad categories of business activities. A census of existing shops is first carried out from which samples are selected, through a systematic sampling technique with a random start. In all, 42 units (approximately 8 from each of 5 markets) in 7 broad sub-sectors were selected for interview.

3.5.12 Sampling for Industrial Units

As is envisaged, the wide range of sectors and sub-sectors and even wider range of industrial activities, certainly poses severe difficulties in selecting the sample. Since the study is expected to produce 'average' damage data sets for the industry sector as a whole, the investigation needs to include activities as much as possible across various types. Hence, it is not feasible to use a rigorous sampling design. The investigation thus essentially needs to be based on an approach, in which case the resources are available for a pre-determined number of sample, namely 60 units (for the main case study area). In the absence of any sampling frames, the systematic sampling technique is adopted. The places/roads of main concentrations of industries are first identified, and then 5 locations are selected and the number of activities listed in each of the locations. Finally, 12 units are chosen from each of the 5 locations by a systematic sampling technique. In all, 60 entrepreneurs from 5 groups of activities were interviewed. However, two units were subsequently excluded because of detection of some inconsistencies in information.

3.5.13 Sampling for Office and Public Buildings

Flood loss potentials in office and public buildings are contemplated for only the main case study area, where there is high presence of public buildings and offices. Nearly 400 public buildings are located in the area, a list of which was prepared. A total sample of 20 units were selected at random. Later on, however, one unit was excluded because of incomplete information.

3.6 Survey Instruments and Sample Size

The principal survey instruments comprise separate interview schedules for four sectors under study, which are presented in Appendices G through to I. The schedules were pre-tested in the three study areas, and subsequently modified suiting the local and flood conditions. The schedules were administered by trained and experienced investigators. A four-week survey training is provided, approximately two weeks in the office and two weeks in the field. The total number of sample units by sectors is shown in Table 3.2.

Table 3.2: Number of sample units by sectors

Study area	Flood type	Sectors			
		Households	Industries	Business	Office
Tangail (Main study area)	1988 river flood	144	58	42	19
Bahubal (Habiganj)	1993 flash flood	122	32	31	-
Khatunganj (Chittagong)	1991 tidal flood	90	31	30	-
Total		356	121	103	19

3.7 Informed Opinion

In order to obtain fairly accurate and compatible estimates of damages, however, some prior idea of the value of properties and damages under different flood and other conditions were sought from secondary and informed sources. Some key-informant interviews and expert opinions were also sought on various aspects relating to construction techniques, construction materials and costs of various constructions. Following that in Bangladesh there are few agencies dealing with housing prices[26], these data were collected from contractors and builders who are engaged in civil construction. Repair and replacement costs of various items of construction for various types of houses were collected. Market prices of construction materials were procured from manufacturers. The prices of major household inventories were procured from markets, keeping in view of variations in size, design and quality in order to cross-check with those obtained from sample respondents.

In addition, the knowledge and experience of Public Works Department (PWD), was profitably utilised in this regard. The Department, responsible for inviting public quotations and implementing and supervising construction works, maintains the detailed item-wise costing schedule for different building fabrics, especially the brick buildings (BB). They maintain the costs, updating from time to time. The estimates were checked with those collected from the relevant experts, including the builders and contractors. For other low-cost houses like MT, MM, BC and MC type, the research largely depends on structural engineers and other relevant experts[27].

Macro-level Study and Land Use Survey

The research comprises two major components: flood impacts at the micro level (based on primary source of information) and flood impacts at the macro level (based on secondary sources of information). This Chapter is concerned with the methodology of studying flood loss potentials at the micro-level. The methodology of investigating flood impacts at the macro level is described in the relevant chapter (Chapter 8). In order to demonstrate the

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[26] The only organisation, namely House Building Research Institute carries out research on low-cost housing; unfortunately, however, they have little information on costs of various existing constructions.

[27] Besides, the study team carrying out the field survey consists a part-time civil engineer and a surveyor.

applicability of existing appraisal methods (e.g. unit-loss model) an additional survey e.g. the land use and land level survey is undertaken in the main case study area, the methodology of which is described in the relevant chapter (Chapter 7).

3.8 Summary

The present investigation entails urban non-agricultural impacts which, by analogy, also embodies rural non-agricultural impacts. The study concerns flood loss potentials in major five sectors of the urban economy. The preceding discussion describes how the study is actually implemented.

The study focuses more on indirect impacts, including the linkage effects in commercial sectors. In the residential sector, the study focuses on direct impacts. Field research, which encompasses loss data generation, is itself a major component of the research. Given that an urban flood study entails study of a large domain of sectors, and wide range of impacts and their assessment methods, and given limited endowments in terms of material and time, this study should be viewed as a 'case demonstration' of research on flood impacts. Hence, the present investigation is to be conceived in the framework of certain set boundaries.

The research uses three reference floods: a river flood, a flash flood and a tidal flood occurred in three urban areas in Bangladesh. The research which is an empirical study dealing with largely the quantitative analysis adopts survey methods - the methods which resort to some sampling techniques. However, the investigations are confined within a few case study towns. One of the towns is taken as a case study area for demonstrating appraisal methods. In combination with the sample survey methods, the research also employs some 'triangulation' and Rapid Rural Appraisal techniques. Additionally, the survey seeks some qualitative information, in order to better reveal, understand and categorise flood impacts. In total, flood damage in 356 households, 103 business, 121 industries and 19 offices has been investigated in three areas.

It was earlier suspected that the research will suffer from the problem of recalling information in the case of the 1988 flood. In the actual data collection, fortunately, this has not appeared so; the 1988 flood experiences are so vivid in memories that the recapitulations emerge not very difficult. In the face of another major flood just in the preceding year (1987 flood), however, the damage estimates for the 1988 flood pose some problems. Care is taken so that damage estimates are attributable exclusively to the 1988 flood.

The evaluation of the flood damages and their quantification uses multiple sources of information. The spontaneous estimates made by the victims are the principal source of information, but most often these are substantiated and verified with the standard information obtained through the informed sources.

CHAPTER 4: FLOOD LOSS POTENTIALS AND ASSESSMENT METHODS - RESIDENTIAL SECTOR

4.1. Introduction

This Chapter is organised into two main sections. In line with the objectives of the research, the first main section seeks to present a discussion[28] on practical problems associated with different approaches of the residential flood damage estimation. Following this, the research seeks to evaluate suitability of the methods in Bangladesh socio-economic and flood conditions. In the end, the section generates an appropriate potential data set on the residential sector[29] - the data set which is subsequently to be used as an input to the modelling of expected annual damage in the main case study town. The next section is an empirical analysis designed to probe further into flood damage and to test some hypotheses implicit in the findings in the first section. The problems of damage data collection and assessment, with a special reference to actual flood surveys and synthetic approach, are discussed in Chapter 2.

In an economy, be it urban or rural, the residential sector is one of the major sectors, which is closely inter-linked with industries or business sector in terms of both forward and backward linkages. Hence, in the whole research, the flood loss potential in the residential sector is important.

4.2 Evaluation of Residential Flood Damage Potentials

4.2.1 Problems of Evaluation of Residential Flood Damage

A brief profile of various evaluation approaches adopted by various studies, including the present research, is presented in Table 4.1. The two major approaches of evaluation of residential damages adopted are the survey technique and synthetic technique. In the USA, the Tennessee Valley Authority (TVA) and the US Army Corps of Engineers (USACE) were

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[28] The discussion is largely drawn from the practical experience gained in the process of field-level survey in the three study areas.

[29] The generation of the depth-damage data sets is, however, limited to the river flood in the main case study area.

Table 4.1: Various approaches adopted by selected studies in generation of potential flood damage data

Country	Research	Damage sector	Damage type	Standard data	Principal methodology
USA	White (1964)	residences	direct indirect	average	survey actual floods
USA	Kates (1965)	residences	direct indirect	average	survey actual floods
USA	TVA (1969)	mostly residences	direct	synthetic	survey actual floods & synthetic
USA	USACE (1970)	mostly residences	direct	synthetic	survey actual floods & synthetic
UK	Porter (1970)	residences	direct	average	survey actual floods
UK	Parker (1976)	mostly residences	direct	synthetic	survey actual floods & synthetic
UK	Penning-Rowsell et al (1977)	mostly residences	direct	synthetic	synthetic
Australia	Smith et al (1979)	residences & business	direct indirect	average	survey actual floods
UK	Parker et al (1987)	industries business office & other urban sectors	direct indirect	average	perception at hypothetical floods in relation to vertical position: 'average' approach
Bangladesh	Present study	residences industries business & office	direct indirect	average	survey actual floods & perception at hypothetical floods in relation to actual floods: 'regression' approach

TVA - Tennessee Valley Authority;
USACE - US Army Corps of Engineers

perhaps the first agencies that adopted the synthetic approach in the evaluation of flood damage in the residential sector. In Australia, flood damage assessments centred around establishing relationships between depths of flooding and damages occurring in actual events (Smith et al 1979). In the UK, the synthetic technique was largely employed for the assessment of flood loss potential in the residential sector (Parker and Penning-Rowsell 1972; Parker 1976; Penning-Rowsell and Chatterton 1977). The present research seeks to assess residential flood losses based on surveys of actual floods, through establishing functional relationships.

In the UK or USA, flood loss assessments in the residential sector based on actual floods is almost certainly impossible. Several reasons can explain this. The residential houses in such countries involves innumerable number of designs, plans and types (a minimum of 21 broad types in the UK, for example), for which an appropriate sample survey covering all the characteristics in the population is insurmountable. In the UK, for six depths and say, three durations, at least 378 (21 x 6 x 3) categories of population are required to be included in the sample. In other words, in order to be statistically acceptable, it needs a sample size of more than eleven thousand (378 x 30)[30]. Added to that, if the six social classes (Penning-Rowsell and Chatterton 1977) are to be incorporated the sample size needed appears to be entirely unmanageable. Additionally, it is nearly impossible that the sample distribution covers various combination of depths and durations. The relationship between damage and flood characteristics (e.g. depth and duration) is often further made complicated by the presence of factors such as perception, warning and emergency actions.

Thus, it appears that few alternatives to the synthetic approach are available in assessing residential damages in the UK or elsewhere in advanced countries. The approach involves methods synthesised from a combination of sources, including 'loss adjusters'. In Bangladesh, on the other hand, it appears that there is no alternative to an interview technique despite that this is fraught with problems (the problems discussed in Chapter 2). This is because there are no informed secondary sources for adopting the synthetic techniques. As is the case with most developing countries, insurance industry (to inventories or stock) in Bangladesh has yet to be developed so that no such sources as 'loss adjusters' are available.

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[30] For any valid statistical analysis, according to Central Limit Theorem, the sample size needs to be at least 30 in each characteristic.

The conditions pertaining to loss assessment approaches are different in different countries, depending on varied flood conditions and property constructions. For example, most usually, warnings are given in American or British floods a fairly long time ahead[31]. In Bangladesh, in contrast, an improved flood forecasting or warning system has yet to be developed. As to the property characteristics, most homes in the USA are of timber-frame constructions, which are highly susceptible to food damage. The British houses which are typically brick-built are not subject to a similar type of structural damages. Thus the flood loss assessments and subsequent construction of 'average' data sets are associated with the type and structure of houses. Before the principles of evaluation of residential damages in Bangladesh are discussed it is important that a brief description of the prevailing house structure and types, around which the appraisal methods are centred, is presented.

House Structure and Type in Bangladesh

Houses in Bangladesh and construction materials used are significantly different from those in countries such as UK or USA. In the UK, for example, at least 21 types of houses are distinguished from constructions point of view (Penning-Rowsell and Chatterton 1977). These houses are typically brick-built with floors commonly made of floorboards and wooden frame, whereas the American houses are typically built of a timber-frames[32]. An important characteristic of some British (and perhaps, American) houses is that the houses have basement floors or cellars. In contrast, the Bangladesh houses have no such basement floors. An overwhelmingly large proportion of houses in the country, as a whole, are *kutcha*[33]. In urban areas, again, *kutcha* houses are dominant - about more than one-third, a vast majority of which are squatters and illegal settlers. A small proportion of houses in the country are *pucca*[34]. Unlike in the UK or elsewhere in advanced countries, floor materials used in

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[31] In large catchments (e.g. Mississippi) the lead time is long, often a few days; in case of small catchments, for both American or British floods, typically lead time is fairly long, at least few hours.

[32] For example, in the Tennessee Valley and tributaries areas 90% of the houses are built of timber, sometimes with a partial brick veneer; few houses are built of brick (Parker 1976).

[33] *Kutcha* refers to a house type, having both wall and roof materials made of simply straw and bamboo; according to BBS (1991), about 45 per cent of the houses in the country represent this type (as of 1990).

[34] *Pucca* refers to a house type, made of rod, cement and concrete (RCC). This type of house constitutes 16 per cent of the total houses in urban areas (BBS 1991).

Bangladesh are almost invariably made of cements and bricks (in case of *pucca* houses) or mud (in case of *kutcha* ones). There are very few, if any, houses which use wood or similar items in building their floors.

Houses having planned lay-outs are few and far between; other than for *pucca* and raised buildings, houses hardly require any formal lay-outs to undergo construction. In fact, there are barely any building regulations controlling the constructions of *kutcha* and semi-*pucca* houses. One-unit houses are rarely available. Except for multi-storeyed buildings, very few houses are joined to each other. As no house has any basements, potentially there are hardly any damaging effects below floor levels. One other basic difference from, say UK dwellings, is that the houses in Bangladesh, by and large, are plastered both outside and inside. The use of wall papers or materials is rare; instead, they are coated with lime or paintings. Given these differences, so far at least the structural damages are concerned, the damage data sets constructed in the UK or USA are not transferable to Bangladesh.

Four main materials used in the house construction in Bangladesh are: bamboo, corrugated iron (CI) sheet, mud and brick. Timbers are, however, used in all the types of houses, but mainly in doors, windows and wall/roof frames. Following the assumption that the direct damage to houses involves mainly floors and walls - the components which are exposed to direct contact of flood water - houses in Bangladesh can conveniently be distinguished according to type of walls and floors (irrespective of roof materials used). Theoretically there can at least be eight major material combinations, with brick, CI sheet, mud and straw (thatched), which are as follows:

Type	Floor	Wall
B-B*	Brick	Brick
B-C*	Brick	C I sheet
B-M	Brick	Mud
B-T	Brick	Thatched
M-B	Mud	Brick
M-C*	Mud	C I sheet
M-M*	Mud	Mud
M-T*	Mud	Thatched

Field survey indicates that five types (under asterisk *) of houses exist in the three case study areas (see Plates presented in Appendix F). This is also largely true for Bangladesh, as a whole. The house type M-M (mud floor and mud wall), however, is few and far between elsewhere in the country other than in the eastern and western regions (including in the second case study area - Bahubal).

Since house roofs are not usually directly exposed to flood water, these are not taken into account while classifying the houses. The classification of house types with property values and occupants' income is presented in Table 4.2. As can be seen from the Table, the four broad types (in the main case study area) of houses are occupied by four distinctly different socio-economic classes of occupants, in terms of value of structures and inventories, household income and even floor space.

Thus the categorisation of houses into only four types has turned out as the major advantage in the construction of average damage data sets in the residential sector. This also suggests the feasibility of the damage data construction from surveys of actual floods. Nevertheless, this again involves a large sample size. For example, in order to include 5 depths and 3 durations the total sample size for the four house types requires to be in the range of 1800. More importantly, the sample size needs to represent each depth and duration uniformly, which is difficult in a particular area in a specify flood, even in a flood prone locality. Unless this condition is fulfilled, fairly representative average data sets can barely be constructed. Following the resource constraint, this is beyond the scope of the present research, which seeks to demonstrate various methods of appraisals.

The damage data 'arithmetically' averaged (henceforth called the 'average' approach) from actual flood damages can rarely be consistent with various depths and durations. Several reasons can explain this. First, the actual damages do not reflect the 'potential' damage in that there are varied extent of damage-reducing measures among floodplain users. Hence, actual damages are not expected to portray close relationships with flood variables such as depths and durations. Second, the damage data sets are inconsistent because of the large variations in damages and a highly skewed distribution over depths and durations. This is more critical given a small sample size. As an illustration, an attempt was first made to construct data sets from the present survey data through the 'average' approach. Not surprisingly, even though an appropriate sampling design is adopted, the data sets (not presented here) proved to be theoretically inconsistent with various depths and durations.

Table 4.2: Characteristics and categorisation of house types: means from sample households in selected areas

Values shown in 1992-93 (000) Taka; 65 Taka= £ (approx).

	House types				
Area/Value	Brick(floor) Brick(wall) -BB	Brick(floor) CI sheet(wall) -BC	Mud(floor) CI sheet(wall) -MC	Mud(floor) Thatched(wall) -MT	Mud(floor) Mud(wall) -MM
Area 1: Tangail					
Value of building	163	109	65	15	-
Floor height (cm)	33	27	25	24	-
G Floor space (sq m)	59	56	46	25	-
Value inventories	149	103	73	23	-
Annual income	112	76	70	38	-
Per capita income	16	13	12	6	-
Area 2: Bahubal					
Value of building	148	-	60	9	11
Floor height (cm)	34	-	31	33	36
G Floor space (sq m)	45	-	37	24	26
Value inventories	64	-	31	7	11
Annual income	56	-	35	13	20
Per capita income	7	-	5	3	3
Area3:Khatunganj					
Value of building	147	116	70	22	-
Floor height (cm)	30	22	17	20	-
G Floor space (sq m)	76	120	64	43	-
Value inventories	99	133	41	22	-
Annual income	62	83	43	33	-
Per capita income	7	8	5	5	-

Note:

Annual income relates to that earned by all members and from all sources, estimated from pre-flood average monthly income.

- = Not available in the study area

This dictates the need to adopt a different approach (as explained in Chapter 2) that involves predicting damages through establishing functional relationships with flood variables. The approach (henceforth called 'regression approach') appears to be particularly useful for the refinement of data at disaggregated levels of depths and durations. Besides, the act of 'averaging' the damage figures through regressions emerges as more appropriate[35].

As discussed in Chapter 2, one of the problems of generating damage data sets relates to the lack of variations in depths and durations across affected property owners in a particular flood in a specific area. In a bid to surmount this problem, the approach depends first on the actual damages caused at various depths and durations in some actual floods, and then in relation to these, potential damages estimated on some hypothetical flood scenarios[36]. The field experience shows that the approach is realistic so far as the respondents are not pursued for not more than four flood scenarios (2 Depths and 2 Durations). The approach thus involves combining all the actual damages and estimated damages, so that variations in independent variables are diverse and adequate to establish functional relationships.

4.2.2 Principles of Quantification of Damage Values

One of the problems of flood damage assessments involves quantification of damage values. Flood damages are the cost of returning the relevant property to pre-flood conditions. This may be carried out by repairs or replacements of various items of the damaged properties. The value of damages to buildings or inventories thus amounts to total involvement comprising (a) repair works already undertaken (b) replacement works already undertaken and (c) the remaining damages, if any, that are to be carried out in future. The estimates for the unrecovered damages are worked out on the basis of the prices of works that have already been accomplished. Further problems arise as the recovery activities usually take place not at a point in time, but stretched over a range of period, often months or even years. The problem is surmounted by converting these costs at 1992-93 constant prices, through deflating

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[35] The 'least square' estimated regression line or plane passes through observations in such a way that the 'squared residuals' are kept minimum. Averaging through regressions appears to be more scientific as it first considers 'array means' and then estimates the points on the basis of least square principle.

[36] Prior to the main survey, pre-testing was done before deciding on the appropriate hypothetical scenarios and the threshold depths and durations.

by relevant indices for different points (parts of year) in time, as explained in Appendix C.

Present Value of Properties

Ascribing present values to house and contents poses problems. Ideally, present values should equal depreciated values, calculated from original prices, converted to current prices to account inflation. The calculations are cumbersome and difficult. The replacement values are usually likely to be arbitrary and exaggerated. The resale values, on the other hand, are also fraught with some arbitrariness in that the respondents are rarely fully aware of the current market prices of their properties. In spite of this, the 'resale value' approach is adopted, having the advantage that such values at existing conditions can capture the 'average remaining values' of the properties, which is a major issue in flood damage research. For buildings, ground floor values (excluding value of land) are incorporated. Differences in values of different properties are due to many factors; among these are, (a) durability characteristics (b) safety characteristics (c) locational characteristics (d) flood damage (e) flood proneness (f) modifications/extensions (g) age (depreciation), and (h) price inflation.

When the cost of repairs exceed the cost of replacements minus depreciations, it is rational to consider replacement values in order to have estimates of the flood damages. The 'average remaining values', which are the replacement cost net of depreciations, are estimated chiefly through respondents' estimates at existing conditions, in combination with the prior knowledge of second-hand prices. Inventories are valued as if resold (second hand) in current prices according to respondents' estimates, corrected with market prices of similar items. The external appearance and condition of the properties in question are also expected to act as a guide to ascertain depreciation or quality in question. Given that close relationships are found to exist between house types and family income, the relationship is generally also expected to exist between house types and value (and often quality) of contents (which is also evident in Table 4.2).

Care is taken to minimise over and under-estimation of damages. Possible over-estimations arise due to (i) better quality of house constructions (ii) better materials used (iii) claims from e.g. insurances and (iv) respondents' deliberate exaggerations. Likewise, under-estimations arise due to (i) works not done yet (ii) works done by self/family workers and (iii) works done poorly.

Repair/replacement of inventories are estimated net of scrap value, if any. Similarly, loss to stock and materials, livestock and trees is calculated net of remaining residual value, if any.

Wages to labourers constitute a considerable part of losses; labour employed in the process of the recovery includes i) hired workers and ii) family labourers, including respondents' own labours. If family workers are involved in repair/clean-up works, the costs are estimated at the rate of 50% (as opportunity cost) of the existing casual workers' wage rates.

4.2.3 Susceptibility of Building Structure

The following section, drawn largely on the field experience and intensive discussions with relevant experts, describes briefly the susceptibility of various building structures. A brief description of typical damages to various house structures with their threshold depths and durations is presented in Appendix Table A4.1. The house types and some typical damages are displayed in Plates in Appendix F. The building structures (for main buildings) susceptible to the flood damage are divided into four major components: floor, wall, doors/windows and roof. Damages to other house components (stores, toilets, kitchens and livestock sheds) are included in 'other houses'. The flood damages include types (i) damages occurred immediately after events and (ii) damages occurred in consequence or subsequence, such as dampness (to brickwork of floors, walls), increased moisture content, rotting (especially of timber), cracks (especially of walls, roofs) and erosions (to floors).

The extent of damage depends heavily on the type of flood. In other words, depth, duration, velocity and pollutants (e.g. saline water in the case of the tidal flooding) are the major determining variables. Except in cases of prolonged immersion, the brick floors in BB and BC house types are usually unaffected; short duration flooding should not do any considerable damage if the pre-flood condition is good. Damages at short duration and low velocities are not usually no more than the cost of cleaning. If the duration of flooding is long and floodwater has pollutants in it, decorations are damaged in the form of stains on them; the mosaic floors in particular are badly damaged. As the brick and concrete floors are hardly reinforced, sometimes cracks occur which consequently affect floor and house foundations. Extremely long duration flooding generates dampness and fungus. For other types of houses with mud floors, the damages are usually not considerable. In a prolonged flood, however, some muds are washed away, with the creation, at times, of some holes if the pre-flood earth condition was not compacted.

Walls form the major damage component in all house types. In essence, the brick walls are broadly of two types: load bearing walls of 10" (25 cm) width and load bearing RCC columns with 5" (13 cm) walls. The walls of latter (13 cm) type are more susceptible to floods than the former (25 cm wall) type. The 13 cm walls with doors cannot withstand heavy pressure in the case of moderate velocity floods, unless water find ways to pass freely. In BB house types (walls made of brick), the major damage occurs to plasterwork of walls, both internally or externally. The damage usually starts from a height above plinth level, as buildings have an external cement and damp-proof finishing from beneath the foundation up to floor level. A certain amount of water gets behind paint work causing it to discolour or flake when it dries. However, short duration floods are not expected to cause considerable damage to sound plasterwork. Prolonged contact with water, however, often breaks the adhesion leaving no alternative but to renew the plasterwork. Once the plasterwork is damaged, it requires replacing more plaster than is immersed. Although porous brickwork does not exist in Bangladesh, in a long duration flood brick can absorb water to consequently damage plasterwork and result in dampness. In some cases plasterwork needs to be removed and replaced after dying out.

In houses with CI sheet walls, the corrugated iron sheets do not suffer considerable damage unless the flood is prolonged and contains contaminants such as salinity, when these are rusted. In such cases this need repair, repainting or at times replacements if the sheets are too old in the pre-flood condition. Of all the wall types, thatched walls are most vulnerable. If the pillars are heavily damaged, the roofs are eventually likely to be damaged. The pillars in the MC houses are generally of relatively better timbers, which are least affected unless in any extreme cases of poor pre-flood condition. On the other hand, the pillars in MT houses are usually made of bamboos, which are susceptible to a moderate duration flood. Although damages occur up to the extent of flood immersion, the whole thing is scrapped at the end.

In terms of value, the doors and windows form a significant portion of walls, in all house types. The doors are more exposed to damage, since the windows are at a relatively safe height, usually 1.1 metre and 0.75 metre above floor level for BB/BC and MC/MT/MM house types respectively. Timbers vary considerably in terms of susceptibility. Low quality and low cost timbers are generally highly sensitive to water. In general, however, except in the case of the prolonged immersion, the doors or windows should not be extensively affected. Tight surface treatments such as polishes and oil paints are resistant to water for a short period. The most striking feature found is that once a door or window is partially rotten or damaged, no matter how high a quality it is, it almost certainly needs replacement in full.

4.2.4 Susceptibility of Household Contents

A brief description of susceptibilities and typical damages to house contents is presented in Table A4.2. The items of house contents are broadly divided into five categories: (1) domestic items (2) furniture (3) personal effects (4) installation (5) transport and (6) 'other' damage. The domestic items, which comprise mainly electrical appliances e.g. radio, television, refrigerator, cooker and cooking utensils vary to a large extent in their thresholds for damage. For example, a flood depth of 0.15 metres starts damaging a refrigerator while a radio is positioned at a height ranging from 0.50 to 1.5 metres. On the other hand, a television is usually positioned at a height ranging from 0.60 to 1.0 metre. However, only a few owners, who could not raise or move these to a safer height or place, have incurred major damages to such electrical items. In all these cases, the full replacement cost is considered. For example, refrigerators are susceptible even in a short duration flood, as the major part (i.e. the motor) is at a low level (usually at 0.30 meters from floor). Once water enters into this, the whole motor is damaged and thus needs a total replacement. Some minor damages occur due to a damp weather and an increased moisture content. In such cases, some minor reconditioning charges are considered as the cost of flooding. In the case of gas cookers, these are usually placed at 0.30 metres in which case a prolonged flooding (e.g. 1988 flood) has caused rusting rendering it to an almost zero scrap value, when there is no option to a replacement. The short duration tidal flooding associated with salinity also causes total damage to items such as cookers. Utensils are generally lost rather than damaged, in which case replacement values are considered.

Thresholds for furniture items do not vary considerably, but as the items are bulky they can hardly be removed to safer places. At best, these are raised as much as possible. Virtually, any depth of water starts causing damages. In the case of wooden furniture, staining and rotting and in the case of steel furniture, rusting and staining are the common types of damages (See Plates in Appendix F). In either case, damages mostly comprise minor repair and repainting and polishing. Cheaper furniture made of low quality timbers or hardboards or veneered partex need nearly full replacements. Some expensive furniture made of high quality wood needs expensive repainting and varnishing. In the case of tidal flooding (the third case study area), for example, despite the short duration flood, damages to furniture have been relatively enormous, more so in the case of the steel and iron furniture. The repairs often are labour intensive, but for the cheaper items where labour costs exceed replacements, replacement costs are the cost of flooding.

Personal effects comprising mostly ornaments and clothes are raised up so that few losses occur. In the case of the damage to items such as stock of food, books etc, salvage value of which are marginal, and total losses are considered.

Normally little damage to electrical, gas, telephone or water installations occurs. Electrical meters are placed at at least 1 metre height; however, if flooded they are totally damaged and need nearly total replacements. Water meters have little damages. The damage to water pumps is about 75% of the total cost of replacement.

As regards transports, only a few people possess a car in the main case study area. However, in the area of tidal flooding many people have personal cars, in which cases damages are enormous. Damages to other transports (e.g. bikes, motor cycles) in all the flood types are considerable.

Damages to livestock (including poultry), trees and gardens, are categorised as 'other damages'. Livestock and poultry, which are important productive resources to non-farm employments and incomes in urban and semi-urban areas of Bangladesh, are subject to considerable damages in widespread floods. Resale values of losses to livestock and poultry are assumed to be the cost of flooding. In the case of flash floods, damage to cattle is usually low, as these are usually moved to safer places. In the case of other floods, loss is often serious. Damages to poultry are either zero or full. Trees and gardens refer to fruit trees and kitchen gardening, the sub-sector that is managed more often by women folk. In the case of even the short duration flooding full damages are caused to kitchen gardens. Some fruit trees (e.g. jack fruit) are also susceptible to floods; the losses to such trees are considerable.

By use of these sources of evidence and information of susceptibility discussed above, flood damages are estimated for each of the major items of house structure and inventory.

4.2.5 Modelling of Direct Damage in Residential Sector

The relationship between damage and flood characteristics (e.g. depths and durations) is often complex. It is frequently made further complicated by the presence of factors such as perception, warning and other actions. What follows is that damage is not likely to be expressed in any deterministic function. However, statistical curves can be fitted to empirical damage data. As discussed in Chapter 2 (Section 2.4), a typical depth-damage statistical function can be of the form: $D = a + bX + cY + dZ + U$ where, the dependent variable D is damage; X, Y, Z are the independent (explanatory) variables, say, Depth, Duration and Floor Space; a,b,c are regression coefficients and U is random disturbance. The random disturbance may be due to sampling error, specification or measurement error. Given that the specification and measurement errors are kept to a minimum, the regression analysis provides some statistical interpretation of results based on the existing sample and thus an educated judgement of the likely damage is produced.

Flood depth is the prime determining variable of flood damages. As the field survey depicts, duration is likely to be the other major determining variable in Bangladesh, unlike perhaps in some countries such as UK[37]. For example, it is likely that little or no structural damage to some house construction (e.g. BB type) is caused with a flood duration of, say, 3 days. On the other hand, given a fixed depth of flooding, a critical magnitude of duration (say, 3 days), can only cause damage equal to 10% (say) to some house structures (e.g. MC, MT or MM). But any slightly longer flood is likely to cause additional damages up to 90% of the total damages through rotting, saturation or dissolving of mud floors, or collapsing of the house altogether. Additionally, a longer flood is likely to add significantly to damages arising out of dampness, penetration, rotting of timbers and corrosion of corrugated iron sheets. This is more so in the case of the flood water containing pollutants or contaminants (e.g. siltation in normal river flooding or salinity in coastal flooding). Likewise, some inventories (e.g. furniture, steel or wooden) are subject to marginal damages, more than proportionately, as the duration becomes longer.

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[37] The divide between short and long duration, 12 hours, 12 hours and above (Penning-Rowsell and Chatterton 1978; Parker et al 1987), in the UK, for example, appears to be narrow (not surprisingly, perhaps, due to its flood characteristics). In contrast, in Bangladesh there are scarcely any floods (other than a tidal, or perhaps flash flood) lasting less than 7 days, ranging up to as long as more than 30 days (e.g. in 1987 and 1988 flood).

Floor space is likely to be another explanatory variable. However, inventory damage may not always be proportional to floor space. For example, a relatively large house (inherited, say) may contain relatively fewer contents (and so fewer damages) than a small house containing more contents (hence, higher potential damage). In consequence, floor space may not truly explain inventory damages. This is evident from the insignificance of some of the relevant coefficients (e.g. AREA) on regression results (Appendix Tables A4.5 through to 4A.12).

4.2.6 Results on Flood Loss Models and Generation of Average Data Sets

Given that relationships of damage with explanatory variables are complex, a variety of functions are tested, both for actual damage and those adjusted for damage reductions. Several hundred regression models were run in an iterative process, incorporating different damage components and different combinations of variables. Some of the revealing results of those models using only potential damages (i.e. through adjusting by damage-saving activities) are presented in Appendix Tables A4.5 through to A4.12. The definitions of the dependent and independent variables are presented in Table A4.3 and a note on the models and data generation is presented in Table A4.4. The models based on actual damages do not generally provide a good fit, as the damages occurred in actual events do not reflect the potential damages due to the fact that some damage-reducing actions are always inevitable[38]. Additionally, these models are constrained by smaller sample size and not all the regression coefficients are found to be statistically significant, with generally low values of R^2. The explanatory powers of these models are, however, enhanced on inclusion of the variables such as 'proportion of inventories moved' or 'time between perceived and water entered into properties'. The results of these models are not presented.

The models based on potential damages are finally used to generate the damage data sets. The explanatory variables include (1) Depth (2) Duration (3) Floor space and (4) House type. The duration variable is used as a dummy variable. Given that the duration variable is an important explanatory variable, even more so than depth in a few cases, it is desirable that depth-damage data are disaggregated at durations, as well. However, it is more logical to

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[38] In Bangladesh, for example; usually floods do not quickly come and the time-to-peak flow interval is long so that floodplain users can perceive well before it actually enters into the property. This allows the occupants to take some damage-reducing actions.

consider for ranges of durations, rather than for every count of days[39]. In constructing damage data sets through regression models it appears that the magnitude of critical duration is 7 days. Hence, the data sets are generated at two generalised duration categories, 'up to 7 days', and 'above 7 days'. House types are used as dummy (categorical) variables. Ideally, it is intended that through combining all house types the single models are used in the prediction, as these portray higher correlation (implying higher explanatory powers of the models) given a much larger sample size. However, in some of the cases, the categorical variable, house type, in the combined models has not demonstrated a statistical significance. In such cases, the individual models for individual house types are used to generate the data sets.

The damage data refer to direct damages in the main case study area (i.e. for the river flooding). The models using the potential damages, presented in Tables A4.5 through to A4.12, are found to be suitable for use in generating potential damage data sets. The results reveal that linear models, by and large, do not yield a good fit. Despite the fact that the estimated R^2s are statistically significant for almost for all the linear models[40], the value of R^2s are generally at lower levels than those for double logarithmic ones. Thus the logarithmic form of functions are likely to be more suitable and logical in that they yield zero damage for a zero depth of flooding. In addition, this type of model logically predicts damages at a decreasing rate with increasing flood depths.

There can be two principal approaches in generating standard damage data sets: the models of absolute losses and those of proportional (to value) losses. The results shows that both the type of models for absolute and proportional damages are suitable for modelling damages. However, it is distinctly apparent that damage is more closely related to the value of properties, as shown by relatively higher correlations in the case of proportional (to value) damages than those with the absolute damages.

There are several merits of adopting the proportional approach. One of the advantages is that in urban areas of Bangladesh, local municipal authorities maintain, especially for tax reasons,

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[39] The regression results presented reflect that almost all the models (except for 2 cases) have statistically significant coefficients of duration, almost all of which, are at 99% level of significance.

[40] This is so for large sample size.

an inventory of local properties by construction type, land use and value. This is, however, true for the value of structural components. For value of inventories, use can be made of some secondary sources (e.g. BBS - Household Expenditure Survey). Additionally, it is also feasible that the representative value of properties are estimated through some sampling techniques. Once the proportional damages are constructed, generalised absolute damages can be generated for uses of at least intermediate level appraisals.

It would be ideal to use per square metre damages, rather than using damages per unit of establishment, except in the case of desk level appraisals. This is because of the presence of a few extreme values in properties value, stock and, more importantly, damages. However, per square metre damage regressed on explanatory variables shows no significant relationships. Not all the coefficients are significant. Moreover, not all the signs of the coefficients are as expected. Intuitively, this is because of the fact that variations in floor space, particularly, within house types, are not found to be large enough to exhibit adequate relationships, as opposed to the value of the properties. Hence, per square metre damage data sets are derived from per unit damage data, using average floor space.

Thus the proportional loss approach (as often used in USA) appears to be more suitable than the areal approach in Bangladesh conditions.

For structural damages to both 'main house' and 'all houses', the models of individual house types are used for constructing data sets for absolute damages. For proportional damages, the individual models are used in the case of the 'main house' while the combined models are used for the case of 'all houses'. For inventories, the prime flood variables, depth and duration are found to be significant in all the models of individual and combined house types, except in only one case of MT house type in which case duration significant only at the 11% level. Hence, the combined model is used for predicting potential damages to inventories.

Because the floor space of 'other houses' is not available, per square metre damage data sets are constructed for the 'main house' only. Inventory refers to those contents of main houses.

The responses in respect of damage estimates for components such as 'other houses', trees and livestock for hypothetical floods are unsatisfactory so that the potential data set constructions for these components are infeasible. However, per household generalised damages for all these components have been estimated based on actual damages caused by the three floods (See Table 4.11, for the river flood).

Thus, the residential standard potential damage data sets are generated at various levels: (1) per household absolute damages (2) per household proportional damages and (3) per square metre damage. Tables 4.3 through to 4.8 present the damage data sets, disaggregated at 8 levels of depths and 2 levels of durations. Although flood damage information is collected at imperial units (in feet), these are converted to metric units (to approximate 0.30 m = 1 ft). The data beyond 1.52 metres are required to be used carefully, as sample observations have no or fewer cases at such high depths so that the extrapolation at these depths requires some assumptions. A few depth-damage curves are presented in Figures A4.1 through to A4.4.

Clean-up costs

The study reveals that clean-up costs are not considerable in Bangladesh[41]. The major clean-up costs usually involve floor coverings, carpets or the silt deposits or stains/fungus formation on floors. Especially among the householders in a secondary town (e.g. Tangail) in Bangladesh, the use of floor coverings or carpets is few and far between. In Bangladesh, the clean-up costs tend not to be counted as a damage which is recovered mostly by family members. Following that there is hardly any use of floor coverings, clean-up costs are usually confused with repair work of floor damages. Also, it appears that the respondents find it difficult to separate such costs, if any, from the costs of the repair work. Thus it is inappropriate to present clean-up costs separately.

Moreover, clean-up costs have no strong relationships with independent variables such as, depth or duration so that construction of potential data sets for clean-up costs at various levels of depths and durations is not feasible (See Tables A4.11 and A4.12). The clean-up costs, if any, are amalgamated with structural damage in the potential damage data sets. However, per household actual costs of clean-up, shown along with other costs, are estimated (Tables 4.11 through to 4.13 in the next section, Revealing of Impacts).

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[41] Perhaps, they are not in the UK either, relative to total damage.

Table 4.3: Per household potential damage by damage components at various depths

Duration = up to 7 days   Value in Taka:1992-93 prices

		Per household mean damage by components			
		Main house structure	All house structure	Inventory	Total
DEPTH	.30m	1361	1679	4925	6605
HTYPE	1	1141	1360	8101	9461
HTYPE	2	1157	1659	6342	8001
HTYPE	3	1759	2131	3699	5830
HTYPE	4	1387	1569	1560	3129
DEPTH	.61m	2229	2767	8060	10828
HTYPE	1	1996	2451	13258	15709
HTYPE	2	2256	3146	10378	13524
HTYPE	3	2693	3262	6054	9316
HTYPE	4	1972	2212	2553	4765
DEPTH	.91m	2960	3690	10640	14330
HTYPE	1	2735	3417	17500	20917
HTYPE	2	3288	4513	13700	18213
HTYPE	3	3412	4146	7992	12138
HTYPE	4	2405	2684	3370	6054
DEPTH	1.22m	3654	4568	13041	17610
HTYPE	1	3445	4358	21450	25808
HTYPE	2	4332	5879	16792	22671
HTYPE	3	4058	4944	9795	14739
HTYPE	4	2781	3092	4130	7222
DEPTH	1.52m	4287	5370	15190	20560
HTYPE	1	4097	5230	24985	30215
HTYPE	2	5328	7169	19559	26728
HTYPE	3	4621	5641	11409	17050
HTYPE	4	3102	3440	4810	8250
DEPTH	1.83m	4911	6162	17315	23477
HTYPE	1	4742	6101	28561	34662
HTYPE	2	6344	8481	22248	30729
HTYPE	3	5158	6305	12979	19284
HTYPE	4	3401	3763	5472	9235
DEPTH	2.13m	5493	6898	19239	26138
HTYPE	1	5343	6921	31735	38656
HTYPE	2	7319	9719	24721	34440
HTYPE	3	5643	6906	14421	21327
HTYPE	4	3667	4049	6080	10129
DEPTH	2.44m	6075	7637	21142	28780
HTYPE	1	5947	7747	34874	42621
HTYPE	2	8317	10987	27166	38153
HTYPE	3	6115	7493	15847	23340
HTYPE	4	3923	4324	6682	11006
Sector average		3871	4846	13694	18541

Table 4.4: Per household potential damage by damage components at various depths

Duration > 7 days | Value in Taka:1992-93 prices

		Per household mean damage by components			
		Main house structure	All house structure	Inventory	Total
DEPTH	.30m	2558	3160	8007	11167
HTYPE	1	2970	3498	13169	16667
HTYPE	2	2607	3727	10309	14036
HTYPE	3	2531	3008	6014	9022
HTYPE	4	2119	2406	2536	4942
DEPTH	.61m	4286	5343	13104	18447
HTYPE	1	5194	6306	21552	27858
HTYPE	2	5084	7070	16872	23942
HTYPE	3	3852	4604	9842	14446
HTYPE	4	3014	3392	4150	7542
DEPTH	.91m	5771	7224	17297	24522
HTYPE	1	7118	8789	28449	37238
HTYPE	2	7408	10142	22270	32412
HTYPE	3	4881	5852	12992	18844
HTYPE	4	3675	4116	5478	9594
DEPTH	1.22m	7196	9036	21201	30237
HTYPE	1	8968	11210	34870	46080
HTYPE	2	9761	13212	27297	40509
HTYPE	3	5806	6978	15924	22902
HTYPE	4	4250	4743	6714	11457
DEPTH	1.52m	8505	10697	24695	35393
HTYPE	1	10662	13454	40617	54071
HTYPE	2	12005	16100	31796	47896
HTYPE	3	6612	7961	18548	26509
HTYPE	4	4740	5274	7820	13094
DEPTH	1.83m	9804	12355	28149	40503
HTYPE	1	12341	15694	46431	62125
HTYPE	2	14296	19056	36168	55224
HTYPE	3	7380	8899	21099	29998
HTYPE	4	5197	5770	8896	14666
DEPTH	2.13m	11019	13899	31276	45175
HTYPE	1	13909	17802	51590	69392
HTYPE	2	16490	21839	40187	62026
HTYPE	3	8073	9747	23443	33190
HTYPE	4	5604	6209	9884	16093
DEPTH	2.44m	12241	15455	34370	49824
HTYPE	1	15480	19927	56693	76620
HTYPE	2	18741	24687	44162	68849
HTYPE	3	8749	10575	25762	36337
HTYPE	4	5995	6631	10862	17493
Sector average		7672	9646	22262	31909

Table 4.5: Potential damage proportion by damage components at various depths

Duration = up to 7 days Value in Taka:1992-93 prices

		Mean damage proportion (to value) by components			
		Main house structure	All house structure	Inventory	Total
DEPTH	.30m	.0359	.0336	.0682	.0466
HTYPE	1	.0072	.0108	.0563	.0301
HTYPE	2	.0110	.0198	.0619	.0366
HTYPE	3	.0318	.0276	.0605	.0406
HTYPE	4	.0937	.0761	.0940	.0793
DEPTH	.61m	.0553	.0558	.1188	.0744
HTYPE	1	.0128	.0179	.0989	.0499
HTYPE	2	.0213	.0330	.1076	.0619
HTYPE	3	.0480	.0458	.1052	.0649
HTYPE	4	.1389	.1266	.1634	.1207
DEPTH	.91m	.0703	.0743	.1618	.0969
HTYPE	1	.0174	.0238	.1336	.0665
HTYPE	2	.0309	.0439	.1469	.0834
HTYPE	3	.0593	.0610	.1436	.0846
HTYPE	4	.1735	.1686	.2231	.1533
DEPTH	1.22m	.0810	.0916	.2033	.1179
HTYPE	1	.0225	.0293	.1679	.0820
HTYPE	2	.0406	.0541	.1845	.1038
HTYPE	3	.0699	.0752	.1804	.1027
HTYPE	4	.1911	.2079	.2803	.1829
DEPTH	1.52m	.0966	.1073	.2412	.1365
HTYPE	1	.0269	.0343	.1992	.0961
HTYPE	2	.0499	.0634	.2190	.1223
HTYPE	3	.0791	.0881	.2141	.1188
HTYPE	4	.2305	.2433	.3326	.2090
DEPTH	1.83m	.1088	.1225	.2787	.1548
HTYPE	1	.0315	.0392	.2302	.1102
HTYPE	2	.0605	.0724	.2530	.1406
HTYPE	3	.0878	.1006	.2473	.1344
HTYPE	4	.2555	.2779	.3843	.2339
DEPTH	2.13m	.1198	.1366	.3137	.1714
HTYPE	1	.0357	.0436	.2591	.1229
HTYPE	2	.0697	.0807	.2848	.1576
HTYPE	3	.0956	.1121	.2784	.1486
HTYPE	4	.2780	.3098	.4324	.2566
DEPTH	2.44m	.1305	.1505	.3487	.1879
HTYPE	1	.0398	.0482	.2880	.1355
HTYPE	2	.0791	.0889	.3165	.1746
HTYPE	3	.1032	.1236	.3094	.1626
HTYPE	4	.2997	.3414	.4807	.2788
Sector average		.0873	.0965	.2168	.1233

Table 4.6: Potential damage proportion by damage components at various depths

Duration > 7 days Value in Taka:1992-93 prices

		Mean damage proportion (to value) by components			
		Main house structure	All house structure	Inventory	Total
DEPTH	.30m	.0586	.0629	.1128	.0763
HTYPE	1	.0185	.0201	.0932	.0530
HTYPE	2	.0252	.0371	.1024	.0642
HTYPE	3	.0432	.0516	.1001	.0629
HTYPE	4	.1473	.1427	.1556	.1252
DEPTH	.61m	.0914	.1045	.1961	.1225
HTYPE	1	.0330	.0335	.1619	.0886
HTYPE	2	.0489	.0617	.1780	.1096
HTYPE	3	.0653	.0858	.1740	.1007
HTYPE	4	.2183	.2371	.2703	.1910
DEPTH	.91m	.1175	.1392	.2677	.1603
HTYPE	1	.0457	.0446	.2211	.1184
HTYPE	2	.0711	.0822	.2430	.1484
HTYPE	3	.0806	.1142	.2376	.1313
HTYPE	4	.2725	.3157	.3690	.2430
DEPTH	1.22m	.1367	.1717	.3363	.1954
HTYPE	1	.0580	.0550	.2778	.1465
HTYPE	2	.0935	.1014	.3053	.1854
HTYPE	3	.0950	.1409	.2985	.1596
HTYPE	4	.3002	.3894	.4636	.2902
DEPTH	1.52m	.1635	.2009	.3991	.2269
HTYPE	1	.0694	.0643	.3296	.1719
HTYPE	2	.1147	.1187	.3623	.2192
HTYPE	3	.1075	.1649	.3542	.1847
HTYPE	4	.3622	.4557	.5502	.3317
DEPTH	1.83m	.1853	.2295	.4611	.2577
HTYPE	1	.0812	.0734	.3808	.1975
HTYPE	2	.1391	.1355	.4186	.2528
HTYPE	3	.1193	.1884	.4092	.2090
HTYPE	4	.4015	.5205	.6357	.3715
DEPTH	2.13m	.2048	.2557	.5189	.2858
HTYPE	1	.0919	.0816	.4286	.2206
HTYPE	2	.1603	.1510	.4711	.2839
HTYPE	3	.1300	.2100	.4605	.2313
HTYPE	4	.4368	.5802	.7154	.4076
DEPTH	2.44m	.2240	.2819	.5768	.3137
HTYPE	1	.1026	.0903	.4764	.2436
HTYPE	2	.1820	.1665	.5236	.3151
HTYPE	3	.1403	.2314	.5119	.2532
HTYPE	4	.4710	.6395	.7952	.4431
Sector average		.1476	.1808	.3586	.2048

Table 4.7: Per square metre potential damage by components at various depths

Duration = up to 7 days | Value in Taka:1992-93 prices

		Per square metre damage by components		
		Main structure	Inventory	Total
DEPTH	.30m	33	98	131
HTYPE	1	19	136	156
HTYPE	2	21	113	133
HTYPE	3	38	80	118
HTYPE	4	55	62	117
DEPTH	.61m	53	160	213
HTYPE	1	34	223	257
HTYPE	2	40	184	224
HTYPE	3	58	131	189
HTYPE	4	78	101	180
DEPTH	.91m	68	211	280
HTYPE	1	46	295	341
HTYPE	2	58	243	302
HTYPE	3	74	173	247
HTYPE	4	95	134	229
DEPTH	1.22m	83	259	342
HTYPE	1	58	361	419
HTYPE	2	77	298	375
HTYPE	3	88	212	300
HTYPE	4	110	164	274
DEPTH	1.52m	97	301	398
HTYPE	1	69	421	490
HTYPE	2	95	347	442
HTYPE	3	100	247	347
HTYPE	4	123	191	314
DEPTH	1.83m	110	344	453
HTYPE	1	80	481	561
HTYPE	2	113	395	508
HTYPE	3	112	281	393
HTYPE	4	135	217	352
DEPTH	2.13m	122	382	504
HTYPE	1	90	534	624
HTYPE	2	130	439	569
HTYPE	3	122	312	434
HTYPE	4	146	241	387
DEPTH	2.44m	134	419	553
HTYPE	1	100	587	687
HTYPE	2	148	482	630
HTYPE	3	132	343	475
HTYPE	4	156	265	421
Sector average		87	272	360

Table 4.8: Per square metre potential damage by components at various depths

Duration > 7 days

Value in Taka:1992-93 prices

		Per square metre damage by components		
		Main house structure	Inventory	Total
DEPTH	.30m	59	159	218
HTYPE	1	50	222	272
HTYPE	2	46	183	229
HTYPE	3	55	130	185
HTYPE	4	84	101	185
DEPTH	.61m	95	260	355
HTYPE	1	87	363	450
HTYPE	2	90	300	390
HTYPE	3	83	213	296
HTYPE	4	120	165	284
DEPTH	.91m	126	343	469
HTYPE	1	120	479	599
HTYPE	2	132	395	527
HTYPE	3	106	281	387
HTYPE	4	146	217	363
DEPTH	1.22m	155	421	575
HTYPE	1	151	587	738
HTYPE	2	173	485	658
HTYPE	3	126	345	470
HTYPE	4	169	267	435
DEPTH	1.52	181	490	671
HTYPE	1	180	684	863
HTYPE	2	213	565	778
HTYPE	3	143	402	545
HTYPE	4	188	310	499
DEPTH	1.83m	207	559	765
HTYPE	1	208	782	990
HTYPE	2	254	642	896
HTYPE	3	160	457	617
HTYPE	4	206	353	560
DEPTH	2.13m	231	621	852
HTYPE	1	234	869	1103
HTYPE	2	293	714	1006
HTYPE	3	175	508	682
HTYPE	4	223	392	615
DEPTH	2.44m	255	682	937
HTYPE	1	261	955	1215
HTYPE	2	333	784	1117
HTYPE	3	189	558	747
HTYPE	4	238	431	669
Sector average		164	442	605

4.3 Revealing of Flood Impacts

4.3.1 Introduction

Given that the research seeks to reveal, categorise and conceptualise flood impacts and thereby accumulate a sound knowledge base of the impacts, this section is an empirical analysis designed to probe further into flood damages and to test some hypotheses implicit in the findings in the previous section. The section aims to widen the empirical base for conclusions relating to such aspects as damage variations according to, among others, flood types, socio-economic groups, perception and warning. The response strategies of the individual floodplain managers are also dealt with in some detail.

Since the three urban areas represent three different floods, the analysis is largely carried out separately for the three study areas. Nevertheless, the analysis is limited to the main case study area where some information is not available in the other areas.

4.3.2 Flood Type and Socio-economic Variations[42]

Flood impacts are analysed in relation to three types of floods: major river flood, flash flood and tidal flood. The study areas are not relatively severely flood prone areas (Chapter 3). Although the main case study town was flooded 7 times during the last two decades, the depths of flooding were not crucial, except in the two worst floods, namely the 1987 and 1988 floods.

The three flood types are not strictly comparable because of the difference in flood characteristics. Flood variables under study and inherent assumptions are shown in Table 4.9 while the differences in the three floods characteristics are shown in Table 4.10. The major river flood of 1988 is a long duration country-wide flood[43]. Although there was no formal warning, the victims could perceive, well before the occurrence, that the flood was going to

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[42] Part of this section is published in a joint paper with Prof Dennis J Parker and Dr Ngai Weng Chan (Parker et al 1997, ISBN 1 85972 551 1). Another research paper based on this section is published in *Bangladesh Unnayan Samikha* (in Bengali, Vol 14, BIDS, February, 1997).

[43] The average depth of flooding across all households in the study area was 0.8 m (st deviation of 0.28) with average duration of 18 days (st deviation of 8.1).

Table 4.9: Flood variables under study and inherent assumptions.

Key flood damage variables	Assumptions
A Flood Characteristics	
1 Depth	At various Durations Velocity, Silts, Discharge assumed constant. (Storm, Salinity, in addition, assumed constant for Tidal flood)
2 Duration	At various Depths Velocity, Silts, Discharge assumed constant. (Storm, Salinity, in addition, assumed constant for Tidal flood)
3 Velocity	Assumed constant
4 Discharge	Assumed constant
5 Silts	Assumed constant
6 Salinity	Assumed constant
7 Storm	Assumed constant
8 Warning	Implicitly no Warning assumed, as none given (major river food); Warning given in other floods;'informal' warning implicit in all areas.
9 Flood-to-Peak Interval	Not taken into account
10 Seasonality	Mostly taken into account
B Property characteristics	
1 Average remaining value	Taken into account
2 Property type	Taken into account
3 Property space	Taken into account
4 Income class	Taken into account
5 Social class	Implicit
6 Perceptions	Taken into account
7 Adjustment	Taken into account
8 Property age & quality	Implicit

Table 4.10: Basic characteristics of three types of flood under study

Characteristics	Flood type		
	Major river flood	Flash flood	Tidal flood
Urban area	Tangail	Bahubal (Habiganj)	Khatunganj (Chittagong)
Sample household(no)	144	122	90
Age of buildings (yrs)	20	15	16
Length of dwelling (yrs)	16	13	14
Ground floor space (sq m)	47	33	71
Floor height(cm)	27	34	23
Major flood variables	(Inundation) Depth, Duration	Inundation Velocity	Inundation Velocity,Storm Salinity
Depth of flooding(m)	.78	.50	1.26
Duration of flooding(days)	18	3.2	6 hrs
Frequency of flooding	1.9	2.5	2.2
If formal warning given	No	Yes	Yes
Lead time(hrs)	-	2.4	32.4
HH believed warning(%)	-	13	2
HH perceived occurence(%)	99	60	14
Perceived before(hrs)	61	1.3	0.16
Hrs between water entered town & property	31	0.97	0.16
Inventories at risk(%)	60	45	66
HH Moved inventories(%)	100	93	13
HH evacuated(%)	64	52	96
Days stayed outside	16	7	6
Household income (annual)	73817	30667	53651
Value of building	87829	54693	88519
Value of inventory	87209	27936	71558

Note: All figures represent averages; all values in 1992/93 TK; HH - Households happen. The flash flood is a relatively short duration flood[44] with an additional damage factor, the velocity. The tidal flood is a even shorter duration[45], which, however, comprises major determining factors: storm, velocity and salinity in addition to inundation. Both for flash flood and tidal flood, a formal warning is given.

Tables 4.11 through to 4.13 present per household residential damage by house type based on actual damage in three different flood types by various house types. It may be recalled from the earlier section (Table 4.2) that the house types adequately represent the socio-economic hierarchies. As is evident from the Tables, the extent of damages due to different types of floods is significantly different[46]. For example, the per household damage averaged over all house types amounts to about TK 19,198 in the case of the major river flood, as against TK 10,230 in the flash flood and TK 61,908 in the tidal flood. Looking at the proportional damages, it is apparent that the most devastating flood is the tidal type, which destroys about 34% of the total assets. This is followed by a flash flood, per household damage of which accounts for 11% of the total assets, as against 10% in the case of the major river flood. Looking at the damage components, it is apparent that inventory damage is the major damage component in the total damages in the case of all the flood types, accounting for 43%, 34% and 47% in the river, flash and tidal flood respectively. The next major component is the structural damage accounting for 31%, 27% and 36% respectively in the three types of flood. Damage to trees and gardens, and livestock is also considerable particularly in the river and flash floods. It is evident, however, that clean-up cost is a minor component in the total damage.

Looking at the damages occurred among house types vis-a-vis the socio-economic classes, the most striking feature is that the low-cost houses (and thus low-income occupants[47]) are relatively more vulnerable to floods. As is evident from the Tables, the lower the level of house categories (and income classes) the higher the percentage of damages to their total asset values. For example, in the major river flood, the percentage of damages to asset values in

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[44] The average depth of flooding across all households in the study area was 0.50 m (st deviation of 0.20) with average duration of 3 days (st deviation of 1.2).

[45] The average depth of flooding across all households in this study area was 1.3 m (st deviation of 0.34) with average duration of 6 hours (st deviation of 2.0).

[46] The differences in damages are also statistically significant.

[47] That low-cost houses correspond to low-income classes is evident from Table 4.2.

Table 4.11: Per household residential damages by house type (major river flood,1988 : Tangail)

Value in 1992-93 TK : TK 65 = £(approx)

House type	Damage components	Damage value	S Dev	% of total damage	Damage as % of asset value
BB	Main structure	7270	6392	30.5	4.5
	Inventory	12103	9237	50.8	8.1
	Clean-up cost	507	373	2.1	0.3
	Livestock	510	1765	2.1	64.6
	Trees gardens	2977	3262	12.5	51.9
	Other houses	440	1596	1.9	18.1
	Total damage	23807	15152	100.0	7.3
BC	Main structure	7216	4238	29.5	6.6
	Inventory	10698	7668	43.8	10.3
	Clean-up cost	449	260	1.8	0.4
	Livestock	503	1836	2.1	51.9
	Trees gardens	3219	4075	13.2	61.6
	Other houses	2340	6291	9.6	39.4
	Total damage	24425	13290	100	10.7
MC	Main structure	4816	3054	28.5	7.4
	Inventory	6294	5670	37.3	8.6
	Clean-up cost	385	298	2.3	0.6
	Livestock	711	2042	4.2	92.3
	Trees gardens	4109	4282	24.3	60.1
	Other houses	575	1746	3.4	26.4
	Total damage	16890	9721	100.0	11.2
MT	Main structure	4199	2808	36.3	28.4
	Inventory	3692	4548	31.9	16.3
	Clean-up cost	190	119	1.6	1.3
	Livestock	611	1770	5.3	73.5
	Trees gardens	2392	6302	20.7	77.2
	Other houses	477	1906	4.1	28.9
	Total damage	11561	12558	100.0	26.2
All	Main structure	5875	4532	30.6	6.7
	Inventory	8197	7723	42.7	9.4
	Clean-up cost	383	300	2.0	0.4
	Livestock	611	1770	3.2	73.3
	Trees gardens	3174	4610	16.5	60.7
	Other houses	958	3548	5.0	31.4
	Total damage	19198	13704	100.0	10.2

Table 4.12: Per household residential damages by house type (Flash flood,1993 : Bahubal)

Value in 1992-93 TK : TK 65 = £(approx)

House type	Damage components	Damage value	S Dev	% of total damage	Damage as % of asset value
BB	Main structure	1490	1224	10.6	1.0
	Inventory	6486	8270	46.1	10.0
	Clean-up cost	89	74	0.6	0.0
	Livestock	4080	5424	29.0	69.8
	Trees gardens	667	1125	4.7	50.9
	Other houses	1257	1370	8.9	19.0
	Total damage	14069	13473	100.0	6.2
MC	Main structure	1512	726	14.0	2.8
	Inventory	3239	2378	30.0	10.5
	Clean-up cost	50	42	0.5	0.1
	Livestock	3897	6062	36.1	98.3
	Trees gardens	720	939	6.7	93.1
	Other houses	1363	1712	12.6	43.9
	Total damage	10781	8665	100.0	11.6
MT	Main structure	2861	2523	52.0	31.6
	Inventory	1182	1486	21.5	17.7
	Clean-up cost	52	51	0.9	0.1
	Livestock	427	456	7.8	98.4
	Trees gardens	284	691	5.2	89.9
	Other houses	694	505	12.6	55.2
	Total damage	5500	3858	100.0	30.7
MM	Main structure	5103	2490	47.6	48.7
	Inventory	3173	3214	29.6	28.9
	Clean-up cost	60	46	0.6	0.1
	Livestock	1279	1788	11.9	93.4
	Trees gardens	476	724	4.4	88.1
	Other houses	623	1520	5.8	48.5
	Total damage	10714	6996	100.0	43.2
All	Main structure	2761	2408	27.0	5.0
	Inventory	3498	4948	34.2	12.5
	Clean-up cost	63	56	0.6	0.1
	Livestock	2395	4383	23.4	83.7
	Trees gardens	534	891	5.2	73.2
	Other houses	979	1377	9.6	32.2
	Total damages	10230	9315	100.0	11.4

Table 4.13: Per household residential damages by house type (Tidal flood,1991 : Khatunganj)

Value in 1992-93 TK : TK 65 = £(approx)

House type	Damage components	Damage value	S Dev	% of total damage	Damage as % of asset value
BB	Main structure	19790	13628	30.1	13.5
	Inventory	33844	34038	51.6	34.5
	Clean-up cost	1952	1251	3.0	1.3
	Livestock	3882	9586	5.9	89.4
	Trees gardens	1585	2938	2.4	77.6
	Other houses	4589	4937	7.0	32.1
	Total damage	65642	39027	100.0	22.5
BC	Main structure	30183	28551	32.8	26.0
	Inventory	45403	61966	49.3	34.0
	Clean-up cost	1305	1338	1.4	1.1
	Livestock	1408	1631	1.5	79.2
	Trees gardens	2152	5298	2.3	90.9
	Other houses	11671	18054	12.7	39.3
	Total damage	92122	87848	100.0	32.1
MC	Main structure	35086	27187	45.8	49.9
	Inventory	29943	23154	39.1	72.4
	Clean-up cost	1766	1365	2.2	2.5
	Livestock	2276	1840	3.0	98.9
	Trees gardens	2067	2832	2.7	98.8
	Other houses	5516	6930	7.2	27.7
	Total damage	76654	57891	100.0	55.0
MT	Main structure	15458	7609	44.5	68.9
	Inventory	14658	12439	42.2	67.7
	Clean-up cost	729	539	2.1	3.2
	Livestock	1585	2003	4.6	92.9
	Trees gardens	139	672	0.4	88.5
	Other houses	2140	3990	6.2	30.4
	Total damage	34709	20721	100.0	64.1
All	Main structure	22518	19477	36.3	25.4
	Inventory	29054	34038	46.9	40.6
	Clean-up cost	1395	1206	2.3	1.6
	Livestock	2417	5774	3.9	90.1
	Trees gardens	1280	2938	2.1	86.4
	Other houses	5244	9460	8.5	33.6
	Total damage	61908	54049	100.0	33.6

the house categories BB, BC, MC and MT are 7.3%, 10.7%, 11.2% and 26.2% respectively. In the case of tidal flood, the corresponding percentages are 23%, 32%, 55% and 64% respectively. Similar findings hold good in the case of the flash flood[48].

As regards susceptibility of building materials to floods, again, the Tables reveal that the lower the costs of construction, systematically higher are the structural damage proportions. For example, for the lowest-cost house type, MT, the percentage of structural damages (to value) amounts to in the range of 28%, 32% and 69% in the three floods respectively, as against 5%, 1% and 14% for the highest-cost house type, BB. The differences are also found to be statistically significant. In other words, one is tempted to conclude that inexpensive building materials are found to be more susceptible to floods[49].

In summary, the study reveals that the householders of low-income groups (particularly the residents of house types MC and MT) are more vulnerable to flood hazard. This finding well corroborates the general contention that the poorest people are the most vulnerable to floods - they have the most to lose in proportional terms[50].

4.3.3 Explaining Damage Variations and Damage Variables

The enormous differences (both in absolute and proportional terms) in flood impacts among different house types lead to postulation that flood impacts are the product of a series of variables acting in a complex interaction with social, structural and other factors. It is thus worthwhile first to explore possible associations between some selected damage variables with the house types. Some analysis, however, follows later in this section, to examine associations among the damage and key explanatory variables themselves.

Table A4.13 in the Appendix presents some tests of associations (X^2 test and test of linear

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[48] Chi-squared values are significant at more than 95% level for all the flood types.

[49] This conclusion is supported also by the potential data sets for proportional damages generated by regression, presented in Tables 4.5 and 4.6.

[50] See, for example, Davis 1978; 1981; 1984a; 1984b; Blaikie et al 1994.

associations[51]) of some selected damage variables with the house type vis-a-vis the socio-economic group. Although the X^2 tests do not yield adequate information about the strength and type of association between two variables, these tests do provide some useful insights as to whether the selected variables are related to the independent variable, house type.

Table A4.13 showing the associations is mainly self-explanatory. However, from among several hundred tests of associations, some major points are outlined. As is evident from the Table, for a host of variables, the X^2 values are found to be statistically significant[52]. The variables such as external condition, floor space, ceiling space, value of properties, depth of flooding and frequency of flooding are generally found to be significantly different among various house types. Threshold heights for the structural and inventory damage are found to be significant, except in the case of the inventory damage caused by tidal flood. Threshold durations for structural damage for all the flood types are found to be significantly different among house types, but threshold durations for inventory damage are statistically different only for the flash flood. Distances of properties from river locations (measured in terms of time taken between water entering town and the one's property) are found to be different among all the residential properties.

Structural and inventory damages, actual and potential, are found to be significant among the house types. The proportion of inventories exposed to floods differs considerably among house types. Damages avoided by any damage-reducing activities are associated with various groups of flood plain users. The estimated clean-up costs vary significantly among house types. The proportion of income lost (to total income) varies among socio-economic groups significantly, except for that in the case of the tidal flood. The variables such as subsequent damage and evacuation operations are also associated with the house types.

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[51] The X^2 test, which is a test of independence by comparing observed and expected frequencies, generally requires that not more than 20% of the cells have expected frequencies less than 5 and none of the expected values are less than 1. This rule was adhered to, except that in a few cases, the limiting cell frequency is taken as 3, as suggested by some statisticians. Where necessary (e.g. in a 2 x 2 Table), Fisher's Exact Tests and Continuity Corrections are performed in order to improve the estimate of observed significance level. The Mantel-Haenszel test of linear association helps providing information of the value of the dependent variable knowing the value of the independent variable.

[52] 95% confidence level is considered as an acceptable significance level, although many results attain 99% level.

Tables A4.15 through to A4.17 are presented (see Appendix) to show whether key damage and explanatory variables are associated in the three flood types respectively[53]. Pearson's correlations among some of the relevant variables are also presented in Tables A4.18 through to A4.20. The correlations are estimated to determine the direction and strength of the relationships.

Since the tables are mainly self-explanatory, only a few points in relation to the damageability of properties are made here. The tables of X^2 associations indicate that absolute structural damages to main house generally are related to house conditions, which is expected. The age of buildings or years of living, however, appears to have no effect on damages in any of the study areas. This is perhaps due to the fact that absolute damages in the total sample have varied considerably while the age of buildings or years of living have not relatively varied widely. Potential damages and damages avoided (by measures) are generally associated with the area of ceiling space, which is postulated. As expected area of floor space also appears to be related to potential damages or damage avoided.

However, absolute damages (structural or inventories) are not related to depth or duration of flooding. This is quite expected, since the actual and absolute damages, which are indeed a part of the full damage, are not expected to portray a relationship with depths or durations, as the responses to hazard among various of property owners are likely to vary to a great degree. Nonetheless, the proportional damages (to values) are generally associated with depth or duration of flooding in the case of the major river flooding. However this is not the case with flash or tidal floods as obviously, in these floods, there are additional damage factors such as velocity, salinity and storm, other than the depth or duration.

The Tables of correlations (Tables A4.18 through to A4.20) indicate that values of the properties (buildings and inventories) are generally found to be positively related to absolute damages. In other words, higher-value properties have the tendency to have higher value of absolute damages, which is expected. For example, the correlation coefficients (denoted by r, significance at 95% level denoted by *) of absolute structural damages with the value of buildings are found to be r=.63* and r=.39* in the case of the river and tidal flood respectively, which are both highly significant. In the case of flash flood, however, no

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[53] For definition of variables, see Table A4.14. As can be seen, not all the variables are measured at interval/ratio scales.

significant relationship exists. Similarly, the corresponding correlation coefficients for inventory damages with their values are .67*, .59* and .85* in the case of the three flood types respectively.

However, the proportional damages (to value), both for structures and inventories, are found to be inversely related to their values, which is again quite expected. For instance, for proportional structural damages the coefficients are estimated as -.50*, -.48* and -.57* in the case of three floods respectively. Similarly, for the proportional inventory damages the relationships are negative and significant in all the three flood types.

Likewise, ceiling spaces are positively related to proportion of contents moved and damages avoided. In other words, in the case of inventories, houses having more ceiling spaces have the tendency to have more damages avoided. This is understandable, as ceiling spaces are used for saving house inventories. The relationship is not, however, present for the flash flood.

With regards to relationships with depths and durations of flooding, contrary to absolute damages, the proportional (to value) damages for structures are generally found to be directly related to depths and durations (r=.51*, r=.26* and r= .58* with depths respectively). Likewise, for proportional damages to inventories, the relationships with depths and durations are also positive and significant.

By and large, absolute damages are found to be positively related to floor spaces, for both structural and inventory damages. Conversely, the inverse but significant relationships are established in the case of proportional damages. As expected house conditions (ordinal variable, from poor to good conditions), show significant inverse relationships with damage proportions to structures in all the three flood types (r=-.40*, -.44* and -.31* respectively). Almost similar findings hold good for the length of internal walls variable. That is, the greater the length of internal walls the more are structural damages expected. This is because, walls generally form the major damage component in the structural damages to houses.

4.3.4 Major Factors in Damage Determination

Depth and Duration - Main Factors and Interaction Effects

In the section on regression analysis (Section 4.2.6), various damage determining variables are analysed. However, looking at the significance level of the main factors is sometimes erroneous in that insignificance of some of the factors do not necessarily indicate that damages are unaffected by them. Hence, in order to examine both the main effects and interaction effects of various damage determining factors, an Analysis of Variance (ANOVA) of the models used in generating damage data sets is carried out. Out of the two sets of models used, the first set of models has the absolute damage as the dependent variable (for three components- main house, all houses and inventories) expressed in double logarithmic form. The other set of models has the proportional (to values) damages as the dependent variable. Nevertheless, only the river flood type in the main case study area is considered in this analysis. As for the other two flood types (flash and tidal flood) there are other determining factors such as velocity, salinity and storm; the measurement of which are beyond the scope of the present study.

The major results are tabulated in Table 4.14. The results show only the 2-way interaction effects. All the higher-order sum of squares are pooled into the residual sum of squares. It appears that the results of the six different models are slightly different. The total main effects and the total 2-way interaction effects are significant at more than the 99 per cent confidence level in all the six models. For the structural absolute damage, two models (for main house and all houses) show that the DEPTH and AREAG (ground floor area) are the two main effects. For these two models, the two interaction effects, DUR with HTYPE (house type), and AREAG with HTYPE are statistically significant. For inventories, the model shows that DEPTH and HTYPE are the two main effects. The two 2-way interaction effects are DUR with HTYPE, and AREAG with HTYPE is found significant in this model.

As regards the structural proportional damage, two models (for main house and all houses) show that DEPTH and HTYPE are the two main effects. For these two models, DUR with HTYPE, and AREAG with HTYPE account for two significant interaction effects. In so far as the model the proportional damage of the inventories is concerned, F values associated with the main effects, DEPTH and AREAG are found to be significant. The observed significance level is more than .03. As for interaction effects, it appears that only the

Table 4.14: Results of Analysis of Variance : major river flood

Source of Variations	DF	LGMHDAM F	LGMHDAM Signif of F	LGALDAM F	LGALDAM Signif of F	LGINVDAM F	LGINVDAM Signif of F
Main Effects	8	16.1	.00	17.6	.00	14.7	.00
DEPTH	2	37.5	.00	33.7	.00	24.6	.00
DUR	1	.5	.48	.5	.49	2.2	.14
AREAG	2	2.8	.05	5.7	.00	.5	.59
HTYPE	3	.8	.50	1.1	.34	4.4	.01
2-way Interactions	23	2.3	.00	2.0	.00	3.5	.00
DEPTH & DUR	2	2.2	.11	1.7	.19	.1	.95
DEPTH & AREAG	4	.5	.71	.5	.74	.2	.93
DEPTH & HTYPE	6	.8	.60	.9	.46	.7	.68
DUR & AREAG	2	.6	.55	.7	.52	.1	.95
DUR & HTYPE	3	4.1	.01	3.8	.01	2.6	.05
AREAG & HTYPE	6	3.9	.00	3.2	.01	10.4	.00
Explained	31	9.1	.00	9.6	.00	17.2	.00
Residual	544	-	-	-	-	-	-
Total	575	-	-	-	-	-	-

Source of Variations	DF	LGPMHDAM F	LGPMHDAM Signif of F	LGPALDAM F	LGPALDAM Signif of F	LGPINVDAM F	LGPINVDAM Signif of F
Main Effects	8	31.1	.00	30.7	.00	25.0	.00
DEPTH	2	36.3	.00	36.0	.00	79.2	.00
DUR	1	.5	.48	.3	.61	3.8	.05
AREAG	2	.5	.58	2.2	.11	3.7	.03
HTYPE	3	22.2	.00	28.5	.00	2.0	.12
2-way Interactions	23	3.3	.00	3.2	.00	2.1	.00
DEPTH & DUR	2	2.2	.11	2.2	.11	.1	.91
DEPTH & AREAG	4	.2	.94	.4	.83	.7	.60
DEPTH & HTYPE	6	1.7	.11	2.7	.02	1.8	.10
DUR & AREAG	2	.7	.50	.7	.49	.2	.85
DUR & HTYPE	3	5.9	.00	6.1	.00	8.3	.00
AREAG & HTYPE	6	5.7	.00	4.8	.00	1.6	.15
Explained	31	31.2	.00	27.9	.00	15.4	.00
Residual	544	-	-	-	-	-	-
Total	575	-	-	-	-	-	-

Note:
LGMHDAM = Log of structural (absolute) damage to main house
LGALDAM = Log of structural (absolute) damage to all houses.
LGINVDAM = Log of (absolute) damage to inventories
LGPMHDAM = Log of structural (proportional to value) damage to main house
LGPALDAM = Log of structural (proportional to value) damage to all houses
LGPINVDAM= Log of (proportional to value) damage to inventories
DEPTH = Depth of flooding; DUR = Duration of flooding;
AREAG = Area of ground floor; HTYPE = House type.

interaction, DUR with HTYPE, is significant at an observed level of .03. The interaction effects, e.g. DEPTH with HTYPE, and AREAG with HTYPE are significant at only .10 and .15 levels respectively.

Thus, the very small F values associated with DUR or AREAG as the main effects in the second set of model of proportional structural damages (main house), for example, do not necessarily indicate that damages are unaffected by duration or ground floor area, since these are included in the significant interaction terms. Likewise, none of the main effects due to DUR or HTYPE in the first set of model for structural damage (main house) are significant, whereas all these effects are included as significant interaction effects. Similar observations hold good for inventory damages.

4.3.5 Other Factors - Velocity, Storm and Discharge

As already mentioned, fine-level estimates of damage-contributing variables, Velocity, Salinity and Storm, are beyond the scope of the present study. However, some gross estimates, based on the experience of the respondents, in respect of the main effects caused by these factors are obtained. As explained in Appendix C, the respondents (of the flash and tidal flood area) were asked to segregate (in %) their total damages caused to them, into each of the three major damage components (e.g. structure, inventory and others) separately on account of Inundation, Velocity (discharge), Storm and Salinity. The estimates are made keeping the respective total component damage as 100, and thus ignoring the interaction effects. (Table 4.15).

In the case of the flash flood, averaged over all house types, it appears that a little less than two-thirds of the structural damages are caused by Inundation alone, and a little more than one-third of the damage is caused by Velocity. For inventories or other assets, the percentage is in the range of 83 and 17 respectively. Nevertheless, it is apparent that there are significant variations in the case of structural damages among different house types. In the case of inventories the differences among house types appears to be small.

In the case of the tidal flood, the Table reveals that the variable, Storm, is by far the most contributory variable; in the range of more than 50% in damages to structure and other assets, followed by Velocity contributing in the range of 25% and 22% respectively. In the case of inventories, however, Salinity contributes the highest percentage (e.g. 42%) to total

Table 4.15: Estimates of the magnitude of damage-contributing (other than Depth and Duration) factors in total damage : Flash and Tidal flood

Damage components /House type	Flood type					
	Flash flood		Tidal flood			
	% of damage caused due to		% of damage caused due to			
	Inundation	Velocity	Inundation	Velocity	Storm	Salinity
Structures						
- BB htype	89.3	10.7	14.9	24.7	50.2	10.2
- BC htype	-	-	11.0	22.9	56.2	9.9
- MC htype	82.6	17.4	23.3	24.0	45.6	7.1
- MT htype	52.7	47.3	21.3	29.7	43.8	5.2
- MM htype	54.1	45.9	-	-	-	-
- ALL	62.2	37.8	17.3	25.2	50.4	8.3
Inventories						
- BB htype	84.8	15.2	26.1	16.4	12.5	45.0
- BC htype	-	-	22.4	18.4	11.6	47.7
- MC htype	81.9	12.1	28.9	21.1	13.3	36.7
- MT htype	81.6	18.4	27.4	21.6	20.4	30.6
- MM htype	77.7	22.3	-	-	-	-
- ALL	83.6	16.4	25.6	18.6	13.7	42.1
Other assets						
- BB htype	69.7	30.3	22.4	17.1	53.9	6.6
- BC htype	-	-	14.7	22.9	51.9	10.5
- MC htype	74.0	26.0	14.0	24.7	54.0	7.2
- MT htype	77.6	22.4	22.1	30.0	43.5	4.4
- MM htype	72.9	27.1	-	-	-	-
- ALL	83.2	16.8	19.4	22.0	51.7	7.6

Note

: The gross estimates provided by respondents have ignored interactions.

: The percentages represent weighted average, weights being the damage value of relevant components of respective properties.

: - Type of house not available in the area damages, followed by Inundation accounting for about 26%. As evident from Table 4.15, generally, the low-cost house structures are found to be relatively more vulnerable to Velocity and Inundation, and the high-cost houses are relatively more vulnerable to Storm and Salinity. So far as the inventories are concerned, it reveals that the inventories of the richer section are more vulnerable to Salinity.

The damages in the two types of floods are not comparable in that the damage factors are different and there can be innumerable combinations of interaction effects. However, in a tidal flood, Storm is the major damage-contributing factor, followed by discharge Velocity.

4.3.6 Perception and Warning[54]

Given that the research seeks to reveal, conceptualise and explain flood impacts, a section on perception and warning was included in the interview schedule. In a study of flood loss potentials, warning and perception are of utmost importance, since the individuals are likely to respond according to their own beliefs and judgements in real situations. Although the present study has no explicit aim of investigating this, the study presents some analysis that reveals the role of perception and warning in the flood loss potential via the behaviour of floodplain users.

Perception and response strategies

Perceptions in flood hazards includes understanding and realisation of the nature of the problem and thus preparing for its probable occurrence and effects. Hazard preparedness and the response process are likely to be heavily dependent on individual perception, whereas the experience and knowledge of the surrounding environment have important bearing on the individual perception capability.

In research literatures, perception is defined as the floodplain users' 'organisation of stimuli relating to an extreme event or a human adjustment' (White 1974). In essence, perception has two aspects: a phenomenal part and a behavioural part (Kirk 1952). The perceived

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[54] Based on this Section, a paper entitled "The role of perception, warning and human factors on flood losses" was presented in EU-ERASMUS conference, London, 6-10 September (1996); this was later accepted for publication as a Research Report in BIDS (forthcoming).

'images', 'ideas' and 'behaviour' derived as a result of the interaction with an individual's environment are viewed as potentially valuable factors in the process of the hazard response (Alam and Chowdhury 1992).

Inevitably, the responses are aimed at reducing the adverse effects of events. Sorensen and White (1980) identified two categories of adjustments based on individual intents: incidental and purposeful. In incidental actions, an individual spontaneously takes some actions to reduce or absorb losses. In purposeful adjustments, however, an individual has several options: 1) accept losses by bearing or sharing 2) reduce losses by either preventing the effects or modifying the events, and 3) radical actions e.g. changing land-use or location. Within this model of decision making, individual perceptions play a vital role in the assessment of alternative options.

Several literatures exist linking perception with various socio-economic variables. However, the findings are diverse. Waterstone (1978) found that longer term residents are more aware of hazard; Kates (1962), however, found otherwise. Davis (1978) revealed that the landless are more vulnerable, while Harding and Parker (1974) found that tenure has no significant relationship with flood awareness.

Baker and Patten (1974) established a clear association between education and perception, which led them to postulate that the floodplain residents with better knowledge and education have a greater awareness of flooding. Subsequent research by Leigh and Low (1983) in a different cultural setting, however, found that no such relationship exists between education and perception. Chan (1995) found that human factors like family ties make floodplain occupants less vulnerable to floods. Waterstone (1978) and White (1973; 1974) revealed that residents nearer rivers are more aware of the hazard and are more likely to make adjustments. Regarding the influence of past experience, the studies such as White (1973; 1974), Harding and Parker (1974), and Parker (1976) revealed that past experience is associated with flood awareness and choice of adjustments whereas Jamaluddin and Ismail (1983) have not supported this. Personality traits are found to be influential in hazard perception in White (1974), while Parker and Harding (1979) concluded that there are no such relationships in their data.

The conclusions derived from the various studies mentioned above are diverse and even conflicting, presumably because the aspects such as cultural setting, hazard type, extent, severity, study methodologies and definitions of relevant variables are not compatible. In line with the discussion above, a few key elements of perception are postulated, which are demonstrated in Figure 4.1. The Figure illustrates the multi-dimensional elements of perception that are likely to ultimately act towards the building up of an integrated judgment capability on the individual's potential reality. A wider formal and informal information network within the community acts as a catalyst in the formation of individual judgment. Based on this judgement, individuals are destined to explore the scope and options to undertake measures to reduce potential hazard effects.

Within this framework of postulations (Figure 4.1), this analysis focuses principally upon an empirical relationship linking perception, warning and human factors to flood loss potentials. This analysis is intended to support or refute some of the findings of previous empirical studies in other countries.

Measurement and Evaluation of Perception

The essence of perception is to reveal how floodplain occupants view the occurrence of an event, including the options available to them in adjusting to the event. In fact, the whole process of flood preparedness may comprise perception, warning and adjustment strategy.

The measurement and evaluation of perception is complex in that the information on perception involves more qualitative than quantitative aspects. However, this research captures the qualitative aspects in two major ways: first, through subjectively obtaining information on attitudes (or degree of threat) towards flood hazard; and second, ascertaining whether the respondents are able to perceive, in advance, that flooding is going to occur at their individual sites. The quantitative aspects are gathered in two ways: first, if perceived in advance, how long before (the actual occurrence) they are able to realise the possibility of flooding; and second, through measuring the perceived time interval between water entering towns and individual's own properties.

Attitudes towards Flood Hazards

Several questions were incorporated into the survey questionnaire in order to assess how floodplain residents view floods including their perceived behaviour. Table 4.16 is presented to show the floodplain occupants' attitudes (or degree of threat) towards flood hazards.

Figure 1 : Typical individual perceptions and action process (to mitigate flood loss)

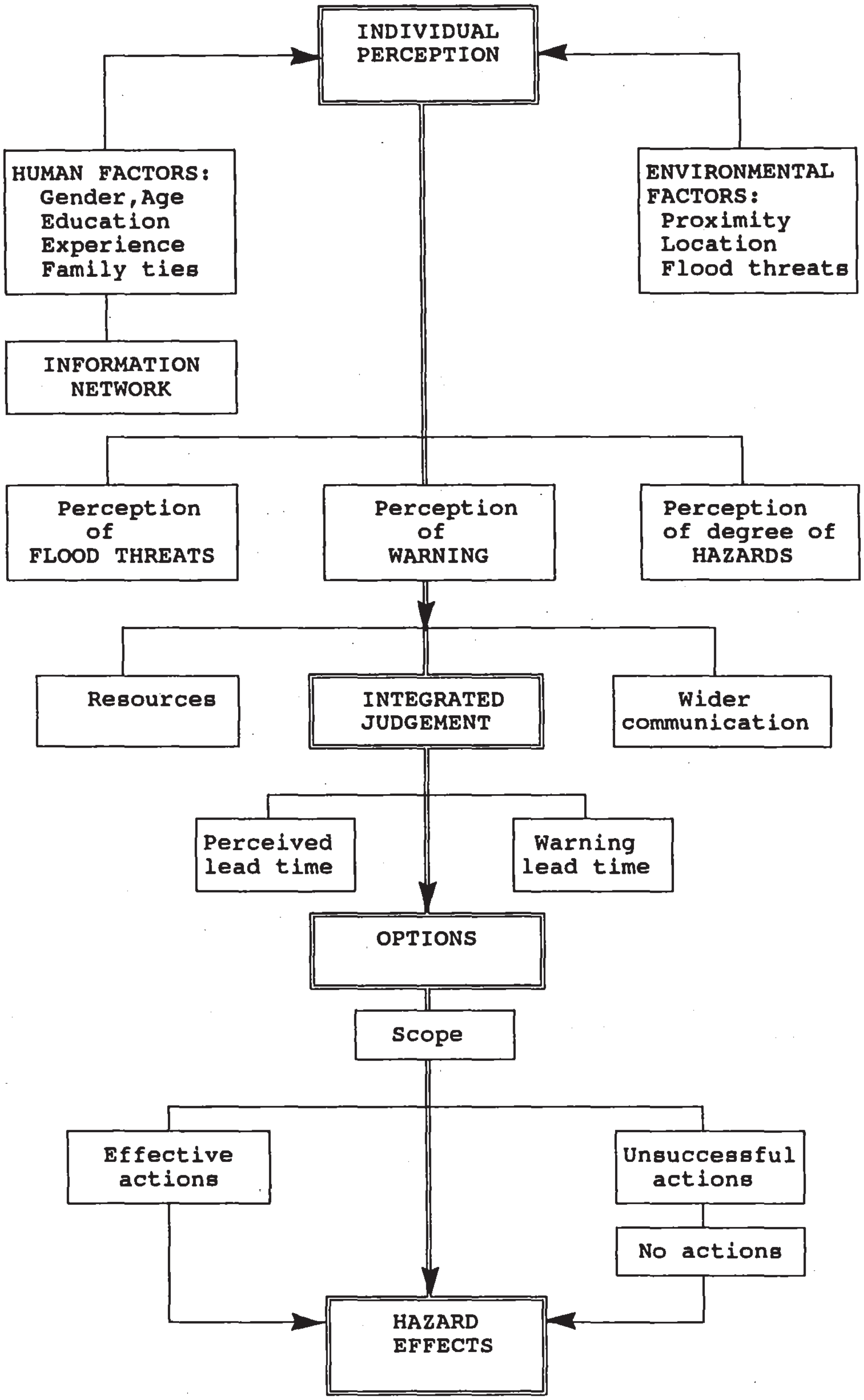

Table 4.16: Flood plain occupants' attitudes (degree of threat) towards flood hazard

Question/Attitude	% of respondents								
	River flood			Flash flood			Tidal flood		
	AG	DA	NS	AG	DA	NS	AG	DA	NS
Been used to floods, so hardly worry?	22	72	6	42	58	-	29	64	7
Very worried when it rains heavily?	73	39	-	50	50	-	64	26	10
Very afraid when floods are forecast?	53	47	-	75	25	-	69	16	16
Check river levels when rains heavily?	22	78	-	83	17	-	11	38	51
Worried when other areas of the country flooded?	44	56	-	25	75	-	32	40	28
Worried when neighbouring areas flooded?	83	17	-	67	25	8	49	40	11
Keep stock of fuel & food on apprehension of flood?	49	51	-	67	33	-	33	38	29
Nothing can be done and must live with floods, act of Allah?	34	66	-	40	48	12	32	28	40

Note:

AG = Agree; DA = Disagree; NS = Not sure

Most respondents gave more than one answer.

The results in the case of flash flood need to be treated with caution, as only 12 (out of 90) respondents answered. They were heavily stressed and thus reluctant to respond at the time of survey, which was carried out immediately after the flood. In the case of other floods, however, all respondents answered.

Generally floodplain occupants of all the three study areas are aware of the threats to flood hazards. In the case of the river flood area 83% of the respondents mention that they become more worried when neighbouring areas are flooded, while about 73% state that they become worried when it rains heavily. There are relatively few respondents who say that they hardly worry (22%), or who mention that they must live with floods as these are the act of God (34%). In the case of the flash flood, some 83% of the occupants report that they check nearby river levels when it rains heavily[55]. After three consecutive occurrences in the past three months, the occupants generally (75%) are quite afraid when floods are forecast. At the same time, however, about 40% of the occupants believe that they must live with floods as these are the act of God. In the case of the tidal flood, about 69% mention that they become afraid when storms or floods are forecast. Particularly when it rains heavily, they (64%) become scared of a cyclone or tidal bore. However, relatively few (32%) occupants report that these are the act of God and that they must live with this.

Awareness of Floods and Warnings

Perceptions of floods are also linked to perceptions of warning systems and their message. No official warning was given for the major river flood, but for the other two floods, formal warning was given. The level of awareness of the warning message among householders appears to be overwhelmingly high, as more than 90% of the respondents in the case of the flash flood, and 98% in the case of the tidal flood mention that they became aware of the warning message. However, it is generally apparent that very few floodplain users believed the message of warning when it was first received. Only 13% of the householders in the flash flood area, and 2% in the tidal flood area believed the message of warning. One reason for not generally believing the message in the flash flood area can be that one such warning message a few weeks ago proved partially false. In the case of the tidal flood area, the householders rarely experienced a tidal surge in the recent past. The average lead time according to sample respondents was about 2.4 hours and 32 hours in the two floods respectively (Table 4.17).

Despite that few householders could rely on the warning, at some later stage however, some started using their own judgement to realise the potential reality depending upon the

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[55] It can be recalled that this urban location (Thana headquarters) has some rural characteristics; the Thana was flooded twice (if not three times in some places) in three months time before the survey.

Table 4.17: Perception of flooding and trust of warning message

If believed message of warning(a)	Flood type Major river flood (b)	Flash flood	Tidal flood
% of hh - not answered	NA	12	-
% of hh - not certain	NA	27	31
% of hh - did not believe	NA	48	67
% of hh - believed message	NA	13	2
Total no of households	144	122	90
Lead time of warning (hrs)	-	2.4	32.4
Time of entering water(Hrs) (c)	31	.97	.16
Lead time of perception(Hrs) (d)	61	1.3	.11
% of hh perceived flooding beforehand	99	60	14

Note:

NA = Not applicable

(a) Believed at the initial stage when the message was received.

(b) No official warning was given in the case of major river flood

(c) Time interval between water entering town and individual's properties

(d) Perceived means realising, for sure (at some later stage), that flooding was going to occur at site.

environment around them. The interactions of the residents with the environmental and other factors appear to be complex. Thus, it is apparent that some of the occupants in the study areas comprehended the occurrence even without warning, and also before the water had entered the town, while some started realising only after the water had entered their locality. On the other hand, some do not show apprehension even on having received the warning or being aware of the water proceeding towards their locality. The analysis shows that in the case of the large river flood and the flash flood, the level of awareness of the time of water entering their town was quite high, which eventually helped residents understand the reality.

Almost all of the occupants (99%) in the river flood area could perceive the possibility of flooding from their own judgement in advance, but at different points in time. The average time interval between the water entering the town and individual properties is estimated as 31 hours. On average, the sample respondents perceived about 61 hours before the actual occurrence (Table 4.17). In other words, most of them realised, fairly long before the water entered the locality, although only a few perceived only after the water entered the town. In the case of the flash flood, about 90% of the households were aware of the breach (reported to be man-made) in the embankment that facilitated the water entering into the town rapidly. However, some 60% of the occupants perceived the possibility of the flood at their own sites only after water entered into the locality. In the case of the tidal flood, despite that only few could rely on the warning, at some later stage, that is at the last hour or more precisely, in the last 10 minutes, some 14% of the sample householders perceived, for sure, that tidal bore was imminent. Most of them, however, realised this only after water had entered the locality or when the storm started. The sample of householders perceived, on an average, only 0.11 hour (or 7 minutes) before the actual occurrence. The average time interval between the water entering the vicinity and individual properties is estimated as only .16 hour (or 10 minutes) (Table 4.17).

Perception capability thus appears to be linked to the size and the type of floods. In a large river flood, the occupants have higher scope of perceptions through a range of information networks including communication links with community members. Flash floods (e.g. in a tidal flood with a storm) provide relatively limited scope for perceptions. The flood-to-peak interval and the state of awareness of the distance of the advancing flood water from property locations appear to have a crucially important bearing upon the perceptions and subsequent damage-reduction decision-making process.

Source of Awareness of the Possibility of Flooding

Table 4.18 presents the sources of awareness of the possibility of flooding. In the case of the river flood, about 51% of the sample respondents became aware either from the rising levels of nearby rivers or from flooding in neighbouring rivers. In the case of the flash flood, rising levels of nearby rivers was the single most important source of awareness of the possibility of flood (57%), followed by flooding in neighbouring areas (35%). Excessive rainfall, newspapers and friends/relatives were also the sources of awareness. In the case of the tidal flood, however, only a few occupants (14%) could perceive the possibility of flooding in advance.

4.3.7 Effects of Perception and Warning

Perception and warning are closely related to flood loss potentials. Besides, flood frequency, which is included as a measure of personal experience, is also likely to have a bearing on flood losses. It is also postulated that certain demographic characteristics such as household structure and the state of the spirit of the community during the hazard would significantly influence the hazard response process.

Hence, the flood damages are analysed as a function of warning lead time, perceived time, time between water entering town and property, and other socio-economic variables. The results for the three different floods are presented in Tables 4.19 through to 4.21 respectively.

The Major River Flood

Table 4.19 presents the results of the major river flood, which was a country-wide flood, inundating about two-thirds of the country. Despite that no official warning was given in this area, nearly all occupants could perceive beforehand, for sure, that the flood was going to occur. In all the cases, flood damages are reduced by either moving contents to safer places or by raising levels at the least. For that reason, the variables PERLEAD (time interval of perception and actual occurrence) and ENTER (time interval of entrance of water into the town and property are considered as influential variables in the process of adjustment strategies. It is also hypothesised that the variable, FREQ (the frequency of flooding vis-a-vis the past experience) would be inversely related to damages. The variable COMTY (the

Table 4.18: Source of awareness of possibility of occurrence of flood

Source of awareness	% of responses by sources	
	River flood	Flash flood
Reading newspaper	18.4	3.4
Excessive rainfall	19.2	3.4
Flooding in neighbouring areas	23.0	34.7
Rising level of nearby rivers	28.1	56.8
Message from friends/relatives	8.7	1.7
Impression from elderly people	1.9	-
Other sources	1.0	-
No of respondents	144	122
% of the respondents perceived of the possibility of flood	99	60

Note :

Each of the respondents (among those who became aware of the possibility of flooding in advance) were asked to mention three most important sources.

The results for the case of major river flood and flash flood are presented, as in the case of tidal flood, only a few residents could become aware of the possibility of occurrence of flood.

Table 4.19: Damage as a function of warning,perceptions and social variables

Flood type 1 : major river flood

Variables	% of Contents moved	Per hh inventory damage avoided (92/93 TK)	Inventory damage avoided as % of potential damage	Struct. damage as % of value of building	Damage to other assets as % of value
WARN : Warning					
-No formal warning given	NA	NA	NA	NA	NA
PERLEAD : Perceived flood before actual occurrence					
-48 hrs before	43.9	8332	51	15	56
-48 - 72 hrs	50.4	8466	54	14	63
-72 + hrs	53.9	12431	58	11	55
ENTER : Hrs between water entering into town and property					
- 12 hrs	37.3	6328	46	14	57
- 12-24 hrs	44.6	7685	53	19	62
- 24 + hrs	58.6	13714	61	9	55
FREQ : Frequency of flooding					
- 1	52.6	9948	56	11	58
- 2	44.6	12082	55	13	56
- 2+	37.8	5766	48	18	60
ADULT :Adult members in household					
- 2	48.9	6358	57	18	57
- 3	49.0	8540	51	15	61
- 3+	49.5	11763	54	10	56
COMTY : Community spirit					
- Lessened	48.2	7133	52	15	64
- Same	52.3	10546	59	10	55
- Heightened	48.8	10751	53	14	55
All household	49.3	9629	54	13	58

community spirit) (measured in ordinal scale) and the variable ADULT (the number of adult members in the household) are also treated as intervening variables.

Table 4.19 reveals that in the case of the river flood, even in the absence of a formal warning, an average householder succeeds in moving in the order of 49% of their inventories by value to safer places, resulting in an average avoided damage for TK 9629. Damage avoided as a percentage of the total potential damages amounts to about 54%. It is evident that percentage of inventories moved to safer places, and thus damage avoided, as expected, systematically increases with increase in PERLEAD and ENTER hours. For example, per household inventory damages avoided, for those who perceives 48 hours before the actual occurrence, is in the range of TK 8332, as compared to TK 12431 for those who realises the possibility of flood more than 72 hours before. Pearson's correlations (denoted by r, and the asterisk * representing two-tailed significance at 95% level) of avoided inventory damages with the variables, PERLEAD and ENTER, are estimated as .30* and .47* respectively, which are highly significant (not presented in the Table). Similarly, the avoided damages as a percentage of potential damages are also found to be directly related to the variables, PERLEAD and ENTER, with the percentages systematically increasing with the increase in the two variables. The relationships, however, are found to be true for only inventory damages. The damages to structure, or other assets are not generally related to the variables, PERLEAD or ENTER. This leads to the conclusion that either the damage-reducing measures for structures or other assets were absent, or the meagre actions based upon perceptions could do little to reduce damages to such assets.

The variable, ADULT (the number of adult members in the family), and COMTY (the level of community sprit in the town) appear to have the tendency to have a positive impact on the damages of the contents avoided. For example, the per household damage avoided estimates as TK 11763 for those with larger than 3 adult members, as against TK 6358 for those having up to 2 adult members (r=.29*). That is, as expected, the more adult members in the households, the greater is the households' capability to undertake damage-reducing measures resulting in more damages avoided. Similarly, the more frequently the community came forward to help, the more it was possible for the victims to carry out damage-reducing activities. This relationship, however, has not been established in the case of proportional avoided damages. The relationship is also not founded in the case of damages to structure and, possibly to other assets, presumably because measures to avoid such damages are limited.

Unexpectedly, however, the frequency of flooding used as a measure of past experience appeared not to have shown any significant negative impact on avoided damages to inventories. Nonetheless, the proportions (to potential damage) of avoided damages are found to have the expected inverse relationship with frequency of flooding; however, the relationship is not found to be statistically significant.

That the frequency of flooding or past experience is not found to have significant negative impact on damages is somewhat disturbing[56]. This is disturbing because, frequency of flooding or the personal experience of the flood victims is expected to be positively related to the levels of perception power, which is, in turn, expected to be negatively related to damages. Nonetheless, one can put forward several explanations for the failure to support the hypothesis in the present analysis. First, the case study town is a moderately flood prone location. The distribution of the sample over the variable, frequency of flooding, is highly skewed towards the frequency of one or two; over and above, it demonstrates no wide variations. Second, the damage variations, considered over the whole sample, vary immensely and widely[57]. Third, the possibility of incorrect recapitulation of the past floods (except for the recent devastating ones) by the respondents, some of whom are not the head of the households and are relatively young, cannot be totally ruled out.

The Flash Flood

In the case of the flash flood area, as already mentioned, a formal warning was given in the late hours of the night and a short while before the onset. But only a few people could have the trust on the message of the warning. Table 4.20 presents the results of the flash flood. The flood was a local one believed to have occurred as result of combined effect of incessant rains in the hilly areas and the breach created in the river embankment.

Almost similar findings as in the case of the river flood hold good in the case of the flash flood. The Table reveals that in the case of the flash flood, an average household moves about 32% of their inventories to safer places, resulting in per household avoided damage of

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[56] In contrasting cultural conditions, Parker (1976) found strong evidence that frequency and recency of personal experience are positively related to flood hazard perception. In other words, frequency is likely to be inversely related to flood losses.

[57] For example, in the case of inventories, the highest damage (TK 27650) is more than 300 times the lowest damage (TK 80).

Table 4.20: Damage as a function of warning, perceptions and social variables

Flood type 2 : flash flood

Variables	% of Content moved	Per hh inventory damage avoided (92/93TK)	Inventory damage avoided as % of potential damage	Struct. damage as % of value of building	Damage to other assets as % of value
WARN : Warning					
- No response	18.9	637	26	25	71
- Not certain	22.4	766	24	32	63
- Didn't believe	26.4	1714	32	25	65
- Believed	44.6	7906	52	3	52
LEAD : Lead time					
- LT 1 hr	29.9	1120	27	26	65
- 1-2 hrs	28.5	1982	30	26	64
- 2 hrs +	35.1	2403	33	25	61
PERLEAD: Perceived flood hrs before					
-1 hr before	24.5	1301	29	20	61
-1-2 hrs	33.1	1487	29	42	68
-2 + hrs	42.3	4771	39	23	63
ENTER:Hrs between water entering into town and property					
- 0.5 hr	29.2	1323	29	29	65
- 0.5-1.0 hr	31.0	2190	29	28	63
- 1.0 + hrs	35.3	2898	35	12	60
FREQ : Frequency of flooding					
- 2	31.9	1940	32	34	63
- 2-3	32.1	2046	29	18	62
- 3+	12.9	560	26	47	74
ADULT: Adult members in household					
- 2	16.7	404	23	30	67
- 3	28.7	1043	27	33	62
- 3+	33.5	2821	34	21	62
COMTY:Community spirit					
- Lessened	32.4	1789	33	21	65
- Same	34.0	6325	31	14	58
- Heightened	24.2	1207	24	40	59
All household	31.7	1943	30	26	63

TK 1943. The avoided damage as a percentage of the total potential damages amounts to about 30%. As is evident from the table, warning has a direct and positive impact on damage reduction. On an average, those who believes the warning moved about 45% of their contents, as against 26% for those who did not. Similarly, those who believes have avoided more damage (Tk 7906), as compared to those who did not (TK 1714). However, warning lead time is not found to have any significant positive impact on damages.

It is demonstrated that generally the damages are inversely related to the level of perceptions, the levels measured in terms of time of perception. The avoided damage as a percentage of potential damages is also found to be directly related to the variable PERLEAD, with the proportions systematically increasing with the increase in the hours of perception ($r = .28^{*}$). The relationship with ENTER, however, is not founded.

As regards social variables, ADULT (the number of adult members in the family) emerges as an influential variable in the reduction of the potential damages, both in absolute and proportional terms. As in the river flood, unexpectedly, personal experience, measured in terms of the frequency of flooding, appears to have little bearing on damages. One explanation could be that some households in the area were flooded three times in two months, so that such victims were purposively excluded in the survey in order to obtain damage estimates attributable exclusively to a single flood. Thus, frequency of flooding is possibly not represented adequately.

The Tidal Flood

Table 4.21 presents the results of the case of the tidal flood. In this case, an average household moves 7.5% of their inventories to safer places; resulting in an average damage avoided of TK 1795. The avoided damages as a percentage of the total potential damages estimate as only about 4%[58]. Nevertheless, it is evident that warning has some direct damage-reducing effects. Not surprisingly, those who believed the message were able to considerably reduce inventory damages (TK 41814 on average), compared to those who did not believe (TK 1363), or who were uncertain about the event (TK 662). Surprisingly, however, unlike in the river flood, this is true even for structural damages, as the percentage

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[58] A few occupants reported that they could hardly take any measures mainly due to infrastructural adversities, following, among others, power failure, lack of transport and traffic congestion in an already congested area.

Table 4.21: Damage as a function of warning, perceptions and social variables

Flood type 3 : tidal flood

	% of Content moved	Per hh inventory damage avoided (92/93TK)	Inventory damage avoided as % of potential damage	Struct. damage as % of value of building	Damage to other assets as % of value
WARN : Warning					
- No response	-	-	-	-	-
- Not certain	3.6	662	2	50	37
- Didn't believe	5.4	1363	5	46	42
- Believed	25.6	41814	39	3	45
LEAD : Lead time					
- LT 24 hrs	5.2	1033	3	47	43
- 24-36 hrs	2.7	555	3	50	36
- 36 + hrs	16.1	5965	8	43	33
PERLEAD: Perceived flood hrs before					
- 0 hr before	0.4	157	1	51	39
- 0-0.25 hrs	12.7	6534	21	18	32
- 0.25 + hrs	26.3	20472	36	22	42
ENTER:Hrs between water entering into town and property					
- 0 hr	5.6	1045	4	47	38
- 0 + hr	10.4	3543	4	50	41
FREQ: Frequency of flooding					
- 1	6.1	1795	15	23	29
- 2	1.7	341	1	62	45
- 2+	3.4	736	2	38	35
ADULT: Adult members in household					
- 2	5.5	1140	5	73	55
- 3	4.3	1394	4	59	51
- 3 +	7.9	1926	4	43	35
COMTY: Community spirit					
- Lessened	2.5	507	1	52	24
- Same	14.3	3509	11	33	16
- Heightened	16.0	6088	11	36	22
All household	7.5	1795	4	47	38

of structural damages (to value) was only 3% for those who believed, as compared to 46% for those who did not. As the storm was the major damage variable, and the lead time was quite long, some of those (particularly of low-cost houses) who believed the warning could possibly adopt some prompt precautionary measures against the storm.

As expected, the percentage of inventories moved (and thus the value of damages avoided) tends to increase with the increase in LEAD, PERLEAD and ENTER hours. Of the social variables, as is the case with other flood types, the variable ADULT emerges as a determining variable in the reduction of the potential damages. For example, the correlation coefficient of the avoided damage with the variable ADULT estimates as .68*, which is highly significant. The relationship of the variable ADULT with the proportional damages for both inventory and structure is inverse, as expected. Likewise, the variable COMTY (the level of community spirit, measured in ordinal scale) has a negative influence on damages, both in absolute and proportional terms.

In summary, the analysis reveals that the individual perception and human factors are important in explaining flood damages and to the hazard preparedness process. The analysis suggests that the level of flood perceptions among floodplain users in Bangladesh is quite high, which has a positive bearing on the resilience-building or the vulnerability-reduction process. Although, generally, warning has some damage-reducing effects, formal warning systems in Bangladesh rarely perform satisfactorily. Following the lack of effective warning systems, however, the local knowledge process and informal warning systems, essentially developed through floodplain occupants' own perceptions and judgements, appear to play an important role in the damage-reduction decision making process. Community cohesion along with family kinship and household structure also play a significant role in the positive response to flood hazard.

4.3.8 Recovery and Adjustment

This section briefly examines how floodplain users generally adopt and respond to flood hazards on their individual initiative.

Adjustments to floods in all the study areas are characterised by the measures, mainly bearing and compensation of losses including some emergency actions. Tables A4.21 and A4.22 (Appendix Tables) present some of the adjustment activities. As can be seen from the

Tables, the measures are more of corrective nature, rather than preventive ones. Loss bearing is by far the most common traditional alternative and is borne by nearly every resident.

In the case of the major river flood, the proportion of recovery to structural damages is about 60% at the time of the survey, which is accomplished in about seven months, as compared to 44% accomplished in about one month and 83% in about one and a half month in the case of the flash and tidal flood respectively. Despite the relatively much higher extent of structural damages caused by the tidal flood, it appears that the proportion of damages recovered is the highest in this flood in a much smaller span of time.

Structural damages in the order of 85% are recovered by employing hired workers. Conversely, most clean-up works (67%) are accomplished by family members. As regards structural measures undertaken in the process of flood preparedness, the river flood victims by a little less than two-thirds took some measures, however meagre. This compares with only 7% and 33% in the flash flood and tidal flood area respectively.

With regards to compensation measures, the respondents were asked to mention three important sources of help they received to make good their losses. Of all the responses, friends and near relatives is the single most common source mentioned, which accounts for about 93%, 43% and 62% of the households in the case of the river flood, flash flood and tidal flood respectively. Considered as the proportion of all support, again, friends and relatives are mentioned as the major support source.

Table A4.22 reveals that considerable help is received from and offered to respondents at the time of disasters. However, in the case of the flash and the tidal flood, very few residents (e.g. 12% and 8% respectively) could offer help to others, as most of them had to keep busy with their own affairs given the suddenness of the events. But a vast majority of the householders received emergency help from others.

With regards to community spirit and role of the affluent section of the society[59], in the case of the river flood, the local community in general and the affluent section in particular have

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[59] The term community and society in this analysis refer the local community and society -excluding outsiders.

come forward to help each other. In the case of the flash and the tidal flood, however, the local community was not in a position to respond adequately, presumably because they are busy with themselves.

In summary, adjustments to flood hazards in all the study areas appear to be characterised by the measures, of bearing the loss and emergency actions including some compensation measures. The measures are dominated by corrective, rather than any preventive actions. Although adjustment strategies regarding inventory damages are highly successful, preventive measures against structural damages appear to be far from satisfactory. As in damage reduction activities, community cohesion and friendliness play a vital role in the compensation and recovery activities.

4.3.9 Indirect Impacts on Household

The assessment of indirect impacts on households, be they tangible or intangible, are fraught with problems. Such impacts may include, among others, damage to health, injuries and stress, loss of lives and loss of income and employment. The problem of evaluating most of the impacts relates to the method of quantification because of the general absence of a market (in Bangladesh), as most of the impacts do not involve goods that are traded in conventional markets.

Table A4.23 (Appendix Section) reveals some indirect impacts on householders in terms of loss of income and employment, and additional medical costs. There is no evidence of significant variations in the number of members suffering health hazards among different house types. It appears that an average householder has some two members affected in all the flood types. Few sample households suffered loss of lives[60]. The diseases to which they fell victim during or immediately after floods are mostly fevers, diarrhoeal and skin diseases. The impact on additional health expenses, measured as percentage of individual's average monthly medical cost, appears to be highest in the case of the tidal flood (153%), followed by 107% in the case of the river flood and 51% in the case of the flash flood. There appears to be a tendency for the proportional cost to increase among the lower-income house types. But the variations are not statistically significant (X^2 not significant).

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[60] This seems very encouraging, particularly in respect of the tidal flood, the event which is reported to have claimed about 150,000 people.

As regards to loss of employment and income at household levels, the table reveals that an average household loses 44, 20 and 22 person days, causing an income loss of TK 5786, TK 1367 and TK 2885 in the case of the river, flash and tidal flood respectively. This amounts to an average loss of 120%, 65% and 62% of their average monthly income in the three floods respectively. There appears to be no definite pattern of variations of losses among various house types. Nonetheless, lower-income households tend to incur higher proportions of losses.

It is reasonable to expect that income losses would be directly related to duration of flood, but for the river flood (with average duration of 18 days) the relationship is not found. Only in the case of the flash flood (with duration of 3 days) is the proportional income loss found to be directly related to duration (r=.39*). Hence, for a long duration flood, there appears to be other factors (aside from duration) responsible for the income loss. For the tidal flood the relationship is not pursued as the flood lasted only about 6 hours.

Table A4.24 reveals some indirect impacts in general, caused by floods in the two urban areas of Bangladesh. The respondent householders were asked, compared to pre-flood (6 months before the occurrence) situations, what were the percentage effects (same, declined or increased, due specifically to flood effects) in their towns immediately after the flood. The aspects on which impacts are sought are income, employment, consumption, prices and wages.

The table does not, however, lead to any conclusive findings, as some householders suggest some increase, while some suggest decline or static situations. Nevertheless, the responses provide some clues of the indirect impacts, in general. Considering the modal values of the responses, the employment and income situations have generally worsened in all the study areas. For example, 60% of the householders in the river flood area suggest a 33% decline in employment, and 70% suggest a 45% decline in income. Consumption of both food and industrial items generally shows a declining trend as a short term effect of the floods. Prices of food items are reported to have increased generally, although some have suggested a decline in a few items. Thus, 90% of the householders in the river flood area and 96% of those in the tidal flood area suggested an increase in the prices of food items, in the range of 23% and 26% respectively.

There seem to have been no considerable impacts on wage rates, either in the agricultural or the industrial sector, as most people suggest that the wage rates were more or less the same. In fact, a considerable number of residents suggested an increase in the agricultural wage rates during a short period in the aftermath of floods[61]. In aggregate, the study reveals that immediately after floods the economic conditions, particularly in terms of employment and income, worsen considerably.

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[61] This could presumably be due to sharp and fast agricultural recoveries when farmers put additional efforts on replanting of the damaged crop, or on the next dry season crop as wet season crops are damaged by floods; the finding corroborates with findings in Chapter 8 (on Macro level Impacts of Flooding).

CHAPTER 5: FLOOD LOSS POTENTIALS AND ASSESSMENT METHODS - COMMERCIAL SECTORS

5.1 Commercial Flood Loss Assessment

5.1.1 Introduction

This Chapter on flood loss potentials and assessment in commercial sectors[62] is organised in two main sections. The first presents a discussion of the practical problems associated with flood loss assessments in commercial sectors, and evaluates the suitability of available methods in the context of Bangladesh conditions. The discussion is followed by the generation of potential loss data sets, which are ultimately used (in Chapter 7) as an input to the modelling of expected annual damages in the main case study town. The subsequent section is an empirical analysis designed to explore flood damages further in relation to various determining factors. The generation of loss data is, however, limited to the river flood area (Tangail), but the empirical analysis entails mostly all the three study areas. Given that the assessment of direct losses is relatively straightforward, the focus of the chapter is on indirect losses, including multiplier effects.

The following discussion points to various practical problems associated with flood damage assessment and data collection in commercial sectors. The aim of the discussion is to provide context to the development of suitable assessment methods to Bangladesh conditions.

5.1.2 Problems of Flood Loss Assessment in Commercial sectors

Following the literature review in Chapter 2, three basic approaches for assessing commercial flood damage potentials can be identified. The first approach, based on actual damage, involves projection of past flood damages into the future is generally based on a set of crude ratios. The synthetic approach was introduced by Kates (1965), who nonetheless recognised the practical problems, mentioning that 'these data seem beyond attainment' for assessing industrial loss potentials. The third approach involves producing damage estimates based on

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[62] In this study, the term 'commercial sectors' is used to refer to a combination of the industries and business sectors, while the industries sector includes manufacture and service sub-sectors, and the business sector refers to retail and wholesale trading. The two sectors, industries and business, are separately dealt with in this analysis.

management personnel's knowledge of potential damages. In adopting the approach Penning-Rowsell and Chatterton (1977) attempted to construct depth-damage data sets for industrial enterprises in the study area of lower Severn in the UK. Not surprisingly, due to great diversity in, among others, size, capital and technology the variabilities in damage figures per square metre were so vast that the study emphasised the 'need to treat industrial units individually rather than to attempt standardisation'.

The three damage assessment approaches basically employ two techniques of data collection: the actual damage data collection technique and the technique of synthesising information. The techniques have both merits and demerits, as discussed in detail in the preceding chapter on residential flood damage assessments. The discussion pertinent to the household sector is almost entirely applicable in the commercial sectors.

In the commercial sectors particularly, the major problem of the use of actual damage data to construct standard damage data sets relates to wide variations manifested in these sectors in their type, stock, capital and technology. The average damage estimates, direct and indirect, to manufacturing plants produced in Parker et al (1987) ('Red Manual'), for example, manifests a great diversity of damage dimensions, at times a few hundred times, across various types of enterprises. The problem is especially crucial for Bangladesh, where the potential diversities across manufacturing units, comprising cottage, small, medium and large are great, besides the heterogeneities within various sub-sectors.

In this context, Tables A5.1 and A5.2 presented in the Appendix Section, reveal basic characteristics of sample industrial and business units in the three urban areas under investigation. The mean estimates of variables such as capital, stock, output and floor space are shown in the Tables. The standard deviations of the variables are presented in Tables A5.3 and A5.4 (Appendix Section), which reveal that the standard deviations of these variables for both the sectors, industries and business, are very high, demonstrating extreme diversities in activities and damageabilities. For example, the standard deviations for the variables, capital and output of the industries sector in the main study area, are estimated as 5 times and 2.4 times as much the mean values respectively. In order to better compare the variations among different sub-sectors, the coefficient of variations are calculated, which are presented in Tables 5.1 and 5.2 for the industries and business sectors respectively. As is demonstrated from the tables, generally the coefficient of variations (CVs) are far above 100 in the case of industries for the damage variables in all the areas (i.e. all the flood types).

Table 5.1: Damage variabilities (coefficient of variations) in sample industrial enterprises : selected areas

(All values in 000 TK at 92/93 price)

Industry type/characteristics	Major river flood		Flash flood		Tidal flood	
	CV	Maximum as no of times of minimum	CV	Maximum as no of times of minimum	CV	Maximum as no of times of minimum
Food and agro-based						
: Total capital	279	730	62	10	81	37
: Annual output	152	500	120	50	139	200
: Stock damage potential	111	1753	55	13300	164	441
: Floor space (sq m)	147	21	188	28	96	23
Cotton and textiles						
: Total capital	220	751	-	-	139	17
: Annual output	166	267	-	-	135	13
: Stock damage potential	171	364	-	-	168	34
: Floor space (sq m)	280	398	-	-	138	19
Timber & furniture						
: Total capital	123	48	96	11	80	5
: Annual output	75	10	159	35	76	3
: Stock damage potential	111	12	157	357	51	2
: Floor space (sq m)	63	8	27	2	118	16
Engineering & electrical						
: Total capital	91	79	57	4	106	52
: Annual output	100	167	72	10	123	25
: Stock damage potential	178	52696	109	3700	110	20
: Floor space (sq m)	75	14	27	2	64	4
Miscellaneous & service						
: Total capital	99	143	217	154	194	102
: Annual output	182	225	271	775	214	90
: Stock damage potential	165	140296	147	458	170	29
: Floor space (sq m)	175	49	63	4	182	56
All industries						
: Total capital	413	6129	180	154	200	1580
: Annual output	244	3333	363	1033	198	750
: Stock damage potential	172	287435	208	125000	302	5852
: Floor space (sq m)	361	697	188	52	165	122

Note: - The case either not available or with only one observation
: Total capital refers to fixed (excluding value of land) and working capital.
: CV = Coefficient of variation, St deviation / Mean x 100.

Table 5.2: Damage variabilities (coefficient of variations) in sample business enterprises : selected areas

(All values in 92/93 TK)

Business type/characteristics	Major river flood		Flash flood		Tidal flood	
	CV	Maximum as no of times of minimum	CV	Maximum as no of times of minimum	CV	Maximum as no of times of minimum
Food and grocery						
: Total capital	90	41	66	7	61	8
: Annual turnover	138	85	130	75	119	150
: Stock damage potential	98	130 Thou	70	7	104	75
: Floor space (sq m)	65	19	48	19	67	9
Cloth & footwear						
: Total capital	28	3	134	16	9	1
: Annual turnover	76	6	27	2	139	13
: Stock damage potential	73	5	102	8	60	3
: Floor space (sq m)	25	2	76	29	10	1
Timber & furniture						
: Total capital	62	7	29	2	57	4
: Annual turnover	101	17	86	8	75	6
: Stock damage potential	63	6	58	4	108	20
: Floor space (sq m)	31	3	29	2	55	4
Electrical & electronics						
: Total capital	35	2	-	-	-	-
: Annual turnover	69	4	-	-	-	-
: Stock damage potential	53	3	-	-	-	-
: Floor space (sq m)	12	1	-	-	-	-
Motor/cycle parts						
: Total capital	64	8	9	1	-	-
: Annual turnover	140	30	0	1	-	-
: Stock damage potential	26	2	57	2	-	-
: Floor space (sq m)	50	4	31	2	-	-
Construction materials						
: Total capital	101	11	74	6	49	3
: Annual turnover	134	27	107	12	110	24
: Stock damage potential	70	4	88	21	76	3
: Floor space (sq m)	20	2	54	3	47	3
Miscellaneous						
: Total capital	78	8	54	4	67	6
: Annual turnover	99	23	49	3	11	1
: Stock damage potential	71	4	74	10	92	20
: Floor space (sq m)	47	5	22	2	37	2
All industries						
: Total capital	104	130	82	16	62	17
: Annual turnover	151	222	130	75	144	150
: Stock damage potential	152	445 Thou	82	28	110	120
: Floor space (sq m)	52	28	52	63	71	12

Note: - The case either not available or with only one observation.
: Total capital refers to fixed (excluding value of land) and working capital.
: CV = Coefficient of variation, St deviation / Mean x 100.
: Thou = Thousand

For example, in the industries sector, in the main study area (major river flood), maximum variability exists for capital (CV= 413) and for floor space (CV=361), followed by for annual output (CV=244) and stock damage potential (172). The most striking feature of the variabilities is that the ratio of maximum to minimum value in these variables is very high, extending up to as large as a few hundred thousands (e.g. for stock damage in the case of the main case study area). This illustrates that the confidence intervals for the mean values of most of the flood variables are very wide. In the case of business enterprises, however, the problem appears to be comparatively less crucial.

Given that the above variabilities apply to only three selected study areas, potentially variabilities across the country are much higher. Thus, it is evident that the large variations in terms of type, size and structure are among the main constraints on constructing average damage data sets from actual flood event in commercial sectors.

Sample size is a crucial determining factor in constructing a fairly representative damage data set. On the other hand, an appropriate sample survey covering all the characteristics in the population is almost impossible, and involves an extremely large sample size. For illustration, in order to include 5 depths and 3 durations in 5 industries groups (say), the sample size covering 30 units in each characteristics required is in the range of two thousand[63].

On the other hand, the construction of average data in the commercial sectors based on synthetic approach is almost certainly impossible in Bangladesh, as well as in the advanced countries. The major reason is the lack of appropriate secondary sources of information, resulting in the failure to construct a susceptibility matrix for a large variety of damage items involved in commercial sectors. In other words, there appears to be no alternative to assessing commercial flood losses through the interview method.

Nonetheless, as argued in residential damage assessments, the data 'arithmetically' averaged from the actual interview survey can hardly lead to consistent stage/damage functions for various reasons. The problem is even more crucial for the commercial sectors. Due to uniqueness in characteristics in the manufacturing premises, the 'Red Manual' thus suggests

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[63] The predetermined sample size of 30 in each characteristics is essential to carry out valid statistical tests.

that a survey of 60% of the manufacturing units in a location would give representative results in most cases. This implies that an extremely large sample size is required to ensure that the data are consistent. As argued in the residential sector, this dictates that the present research adopts an approach ('regression approach') that involves predicting damages through establishing functional relationships with flood variables, which can only lead to fairly a consistent damage data sets. Besides 'averaging' the results through regression, which is more appropriate, such an approach is capable of working out estimates at any conceivable depths or durations based on some assumptions.

The flood damage assessment through the actual surveys is fraught with a host of other problems. One such problem relates to seasonality of operation of activities. In Bangladesh which is characterised by a predominantly agricultural economy, most of the commercial activities, especially in the trading line, are directly or indirectly related to crop economy, and thus a substantial proportion of their business is seasonal.

While discussing the approach of actual flood damage assessment, one has also to recognise that in Bangladesh (and perhaps in many developing economies), the small and cottage industries sector, because of its relatively greater labour absorption capacity, plays a vital role in the national economy[64]. It is likely to be erroneous to contemplate flood losses by combining this sub-sector with the industries sector as a whole. In fact, this sector demands separate treatment in flood loss assessment for many reasons. First, damage characteristics are likely to be notably different because of the nature of operation[65]. The type of enterprises are predominantly labour-intensive using rudimentary machinery and equipment, if any at all[66]. Secondly, the premises are often used for dual purposes including the residential use. Thirdly, about more than two-thirds of labour employed comprises family workers, who run their enterprises more often on order or a day-to-day basis, implying that they hold few stocks of raw materials or finished products exposed to floods (RISP 1981). Fourthly, whilst large and medium industries are concentrated in just few city locations, small

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[64] About 82% of employment and 43% of value added in the total manufacturing sector originates from this sector (The Fourth Five Year Plan, 1990-95, GOB).

[65] As is seen later in this chapter, the flood loss potential of the small-sized units is relatively higher in proportional (to values) terms.

[66] This is, however, valid more for the cottage sub-sector, and the activities in this sub-sector are far more diverse.

and cottage type of activities are almost the only industries in most other urban and semi-urban areas including rural areas.

5.1.3 Principles of Evaluation of Commercial Flood Loss in Bangladesh

5.1.3.1 Introduction

As explained earlier, especially given a small sample size, the standardisation of damages through 'averaging arithmetically' is not feasible. Given the diversities in units, the precision of 'averaging' and the success of standardisation appear to be heavily dependent on the homogeneity of the enterprises. It is envisaged that the diversity can reasonably be reduced to a considerable extent if such damage estimates are standardised to capital employed. In usual conditions, homogeneity in capital is likely to lead to homogeneity in other characteristics such as ground floor area. As will be seen later this chapter, the approach of standardisation by value does not work in this sector, as opposed to in the residential sector.

The field experience shows that a team consisting of experienced (on flood loss potentials) investigators and relevant industrial managers could be an ideal combination in producing best estimates of flood loss potentials for relevant plants. Because interviewers with experience in flood loss potentials are lacking, the research employs interviewers experienced in other socio-economic interviews. However, the research approach profitably employs the knowledge of past floods in combination with that of management personnel. The use of the informed opinion in obtaining a prior idea of aspects, such as the value of properties and damage susceptibilities, is not feasible in the commercial sectors. Nonetheless, for structural damage assessments use is made of the informed opinion that was adopted in the residential sector. Additionally, a general idea of prices of various commodities and merchandise was obtained beforehand from mainly secondary sources.

5.1.3.2 Survey Approach and Instrument

The principal survey instrument comprising interview schedules is shown in Appendix H. The schedule comprises two major components: flood losses assessments and the revealing of impacts. The schedule for the flood loss assessment component used in the research is similar to that adopted by Penning-Rowsell and Chatterton (1977) and Parker et al (1987), with some modifications suiting Bangladesh flood and other conditions. Table 5.3 shows the

Table 5.3 : Major areas of difference in the UK and present study approaches in flood loss assessment in commercial sectors

Approach/Criteria	UK study	Present study
Educational level of commercial respondents/entrepreneurs	100% educated	66% 1 educated
Flood experience of respondents	50%	100%
Availability of flood event	Sparse	Adequate
Major assessment basis	In relation to existing vertical position of stock /inventory	In relation to damage already occurred, and also position of existing stock/inventory
Adjustment for loss-reduction measures	Not arisen since based on hypothetical floods	Adjusted for such measures to arrive at potential damages, as based on actual floods
Warning	No warning assumed	No formal warning, but informal warning implicit
Statistical sampling techniques	Not adopted	Adopted
Methods of data collection	Usually mail questionnaires (some with direct interview), which are relatively cheap	Direct interview, and physical inspection, however, are relatively costly
Standard data produced	Average data, arithmetically averaged	Average data, averaged through regression
Transferability of data	Wider application, usually transferable within country	'one off' site specific data, transferable only in similar damage charecteristics
Level of apparaisal	Mostly up to detailed and refined level	Mostly desk-based to intermediate appraisal scale, but also a few methods for refined scale

Note : [1] In terms of ability to do simple arithmetic or calculation (with or without the ability to read or write), however, the percentage is nearly 100.

areas of differences in the two approaches adopted by the UK (e.g. Parker et al 1987) studies and the present study. The major differences relate to the technique of assessment which differs in that the former uses the existing stock position as the reference point, whilst the latter uses actual losses caused in a past event as the reference point. The UK approach adopts the 'average approach' while the latter employs an approach what may be called 'regression' approach in estimating damages. The major advantage of the UK studies is that the respondents are all educated. The major advantage for Bangladesh is that flood events are plentiful so that direct investigations and subsequent assessments of past events are feasible. Thus, the estimates of damages sought by the research are not entirely based upon hypothetical floods. One of the other advantages of the former approach is that it requires no adjustments for damage reduction measures, while the latter requires adjustment. The data in the former studies are generally transferable within a country, but the 'one off' site specific data generated by the present study are transferable only in some similar damage circumstances.

The method of achieving 'potential' damages from actual damage is similar to that adopted in the residential sector, discussed in Chapter 2.

5.1.3.3 Principles of Quantification of Damage Values

The principles of quantification of damage values largely resemble those employed in the residential sector. It is assumed that flood damage is the cost of returning the relevant property to pre-flood conditions, through either repair or replacement of damaged items. The 'average remaining value' is the replacement cost net of depreciation, which is approximately equal to resale value. This is estimated based on the age and existing conditions of property in combination with a prior knowledge of second hand prices of items. The estimates of damages collected at current prices are converted to 1992-93 constant prices, through constructing appropriate deflators the methodology of which is described in Appendix C.

Susceptibility of Property to Flood Water

Depending upon varied extent of susceptibilities, the direct damage components of commercial premises are grouped into (a) building structure (b) machinery/equipment (including furniture) and (c) stock. The thresholds for depths and durations for different damage components are taken into account before making estimates of damages.

Threshold of damage to machinery/equipment

Table A5.5 (Appendix Section) shows the approximate thresholds of depths and durations for various damage components of sample properties. The thresholds are estimated for the principal items of damage components, machinery/equipment and stock. The susceptibilities of building structure in commercial properties, however, are assumed to be approximately similar to those of the residential sector. On average, threshold for depths in machinery/equipment in industrial units estimates as 14 cms, while that for equipment/furniture in business units amounts to 15 cms (Table A5.5). There appears to be no significant variations in threshold for depths over various types of industrial enterprises (X^2 not significant). The variations of the threshold depth for equipment/furniture over business units, however, varies considerably (X^2 is significant). The average threshold of duration for machinery/equipment in industries amounts in the range of 3.9 days, showing no significant variations over various types of units (X^2 is not significant). In the business enterprises, average threshold of duration for equipment/furniture amounts to 1.3 days (X^2 is not significant).

Threshold of damage to stock

The average threshold depth in industries for stock is estimated to be 11 cms, while threshold of duration for stock is 3.7 days. In both the case of threshold depth and threshold duration, the variations over different industrial units are found to be significant (X^2 values are significant). In the business enterprises, average threshold depth estimates as 4 cms, variations being considerable among types of units (X^2 is significant), while threshold of duration, with an average of 1.3 days, do not vary significantly among types of units (X^2 is not significant).

5.1.3.4 Principles of Indirect Loss Assessment

While formulae for direct loss assessment are relatively straightforward, those for indirect loss assessments are more complex. The indirect loss for industries is the loss to value added on production and that for business is the loss to gross margin on turnover (Parker et al 1987). However, it proves cumbersome to obtain these estimates from the respondents. On the other hand, given that the groupings of 3-digit units available from the secondary sources (e.g. Census of Manufacturing Industries) do not strictly correspond with those obtained in the area under investigation, it is not reasonable to use the information on value added/gross margin from these sources. It is possible, however, to obtain the estimates of net profits of enterprises from the respondents. Hence, for both industries and business, value added and gross margin are estimated by combining wage inputs with net profit.

Recovery of production, if any, is incorporated; additional costs of recovery or working less efficiently are added to calculate firm's total indirect flood losses. For the computation of national or regional loss, coefficients (weighted ratios by type of industries/business) based on respondent's perceptions are used (Table 5.25). The coefficients are incorporated with any production/turnover losses that are likely to have been made up by (mostly) the non-flooded firms in the town, region or the country, as a whole (see Q 38 in the survey instrument - Appendix H). The net balance of the losses left unrecovered are treated as losses for the town, region or nation. The national losses, for example, are estimated as the left over from the subsequent recoveries in town, region, foreign competition, and the country as a whole[67]. None of the sample industrial/business firms in the main study area had branches, so that transferring production within a firm does not arise. Nor are there any firms in the sample units undertaking any foreign business.

Based on the principles previously discussed, the following flood loss estimation formulae are used. The formulae are used to estimate net losses in output, but the ultimate indirect loss to a firm is the loss to value added/gross margin. The estimates of value added/gross margin as percentage of gross output/turnover are shown later in this chapter (Table 5.25).

Formulae

1. PRODUCTION LOSS DURING COMPLETE CLOSURE (TK):
   PDCCLOSE = (CCLOSE * OUT/30).

2. PRODUCTION DURING PARTIAL CLOSURE (TK):
   PDPCLOSE = (PCLOSE * OUT/30) * AVPROD/100.

3. PRODUCTION LOSS DURING PARTIAL CLOSURE (TK):
   PDPCLOS = (PCLOSE * OUT/30) * (1 - AVPROD/100).

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[67] An analysis is carried out in section 5.2.7.

4. TOTAL PROD LOSS DURING COMPLETE & PARTIAL CLOSURE (TK):
TOPDLOS = (PDCCLOSE + PDPCLOS).

5. PRODUCTION LOSS MADE UP (TK):
PDMAKUP = (TOPDLOS * MADEUP/100).

6 TOTAL NET PRODUCTION LOSS (TK):
NTPDLOS = TOPDLOS - (PDMAKUP - ADCOST).

Where,

CCLOSE = COMPLETELY CLOSED DUE TO FLOOD (DAYS)
OUT = MONTHLY OUTPUT (TK)
PCLOSE = PARTIALLY CLOSED DUE TO FLOOD (DAYS)
AVPROD = AVERAGE PRODUCTION DURING PARTIAL CLOSURE (%)
MADEUP = % OF LOST PRODUCTION RECOVERED
ADCOST = ADDITIONAL COST INCURRED FOR RECOVERY

5.1.4 Modelling of Flood Losses

The broad principles of flood loss modelling including the three flood loss (total) models are discussed in Chapter 2. However, it is important to raise a number of points in relation to deciding on the type of model suitable for empirical data in the commercial sectors. Some past studies hypothesised a power function for modelling flood loss (e.g. Aitken 1976; Ketteridge and Green 1994). The exponential function (or the double logarithmic form of function) is likely to be more suitable and logical in that it yields zero damage for a zero depth of flooding. However, the exponential form has the disadvantage of constant elasticities throughout the ranges of the variables. Since this implies that a percentage change in damage for any given percentage change in depths or durations is constant at all levels, the possibility of satiation of damages in varying depths or durations is ignored. Failure to allow for this possibility is a shortcoming of the power form. The loss models therefore includes Depth and Area in power form and Duration and enterprise Group in exponential form, where Duration and Groups for industries/business (I_i or B_i) are used as dummy variables. Use of dummy variable, I_i or B_i, is expected to improve the estimates in accounting for industrial/business type variations. Additionally, this helps yield a more stable relationship facilitated by a larger sample size.

The basic form of the single equation models representing the loss functions, in both linear and power form, is shown in Table 5.4. The structure of the equations, for direct and indirect loss models, is similar. The Ordinary Least Square (OLS) method is used to estimate the regression coefficients. The duration variable, used as a dummy variable, is assumed equal to 1 for duration less than equal to 7 days, and equal to 0 for greater than 7 days[68]. Likewise, the dummy variable, I_i, is assumed equal to 1 for industries i, and assumed equal to 0 otherwise. Nonetheless, multi-collinearity is typically a problem with such types of regression models. While the research is concerned only with predicting damages from the models, the harmful effects of multi-collinearity are expected to be insignificant.

As explained in Chapter 2, the indirect loss models consist of two components: the model for assessing primary indirect impacts, and the model for multiplier effects. In all, three approaches are contemplated in modelling primary indirect losses.

5.1.5 Modelling Multiplier Effects

The study adopts input-output models to assess linkage effects of flooding. Given that input-output tables at regional levels (let alone at a town level) are not available, the national input-output tables (1986-87) are used to construct multipliers for the assessment of linkage effects of flooding. The underlying assumptions and detailed methodology for input-output analysis are discussed in Section 2.4.6.

The multiplier effects can be thought of as operating briefly in the following way. The ultimate effect in output must equal the sum of the direct and indirect effects of the change in the final demand[69]. The decline in output is the first effect which can be called the direct effect. The first-round effects on production in each sector due to this direct effect (i.e. output loss) are then given by the declined final demands multiplied by input-output coefficients. The second-round effects are given by declined final demands in the first-round

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[68] The rationale for using this range of duration is similar to that for the residential sector.

[69] Here direct impacts actually mean what is the indirect losses (production losses) used in the present study, which is termed the first injection to the final demand vector. Indirect effects represent multiplier effects of the first injection, and so on.

Table 5.4: Single equation models used to generate potential damage data set for industries and business units

A. DIRECT LOSS MODELS

1 $D_m = A + B\,(DEPTH) + C\,(AREA) + H\,(D_1) + U_i$

2 $D_m = A\,(DEPTH)^c\,(AREA)^g\,e^{[h\,(D1)\,+\,k\,(Ii)]}\,U_i$

Or, $Log(D_m) = Log(A) + c\,Log(DEPTH) + g\,Log(AREA) + h\,(D_1) + k\,(I_i) + U_i$

Where,

D_m = Direct damage

e = Natural logarithm,

D_1 = a dummy variable for Duration, so that

$D_1 = 1$ when duration up to 7 days.
$D_1 = 0$ for duration for more than 7 days.

Likewise, I_i are dummy variables for 5 Industries groups
so that

$I_i = 1$, for Industries group i
$I_i = 0$, for otherwise, and

U_i = Disturbance factor

B. INDIRECT LOSS MODELS

1 $V_a = A + B\,(DEPTH) + D\,(DURATION) + I_i + U_i$

2 $V_a = A\,(DEPTH)^c\,(AREA)^g\,e^{[h\,(D1)\,+\,k\,(Ii)]}\,U_i$

Or, $Log(V_a) = Log(A) + c\,Log(DEPTH) + g\,Log(AREA) + h\,(D_1) + k\,(I_i) + U_i$

3 $V_a = A\,(D_m)^c\,e^{Ii}\,U_i$

Or, $Log\,(V_a) = Log\,A + c\,Log\,(D_m) + I_i + U_i$

Where,
V_a = Value added loss, D_m = Direct damage, and
other variables as defined earlier.

4 Cobb-Douglas Production model.

$Q = A\,K^{\alpha}\,L^{\beta}\,U_i$

Or, $LOG\,(Q) = LOG(A) + \alpha\,LOG\,(K) + \beta\,LOG\,(L) + U_i$

Where,
Q = Production, K = Capital and L = Labour input used in the production process.

$\alpha + \beta = 1$, $(\alpha, \beta > 0)$, the economies of scale.

I_i are Industries group, i = 1 to 5.

The same set of models are applied to business units, replacing Production by Turnover, Value Added by Gross Margin, and replacing 5 Industries groups, (I_i) by 7 Business groups, B_i. For other assumptions, see Table A5.34

multiplied by the input-output coefficients, and so on for the multiplying effects[70]. Thus multipliers provide measures of the impact of change of one activity on the level of output of all other activities through linkages in the system. Given that multipliers are measures of total impacts in the economy, direct and indirect, the linkage effects in this study are defined as the effects of direct impacts (or, what are called indirect impacts in the terminology of flood loss research).

The augmented input-output table for Bangladesh economy is available for 1986-87. The national I-O Table partitioned the national economy into 53 production sectors, of which broadly 17 are in agriculture, 22 in industry, 3 in construction, 3 in energy and 8 in service sectors. The 53 sectors of the economy are rearranged and consolidated by incorporating the 58 sample industrial units (in 5 broad activity groups) under investigation in the main case study area[71]. Having performed the rearrangement thus, the input-output Table is condensed into 39 economic sectors. Although employment multipliers can also be constructed through input-output models, only output multipliers are contemplated in order to avoid any potential double counting.

5.1.6 Results of Loss Models

Several hundred regression models have been run for both the sectors, industries and business, in an iterative process, incorporating different damage components and various combinations of explanatory variables. Some of the revealing results are presented in Tables A5.6 through to A5.17 (Appendix Section). Only the models which are statistically valid are presented. The results are self-explanatory. Initially, the models are tried using data on actual losses (not presented here); subsequently, in the face of general failure to exhibit adequate relationships of actual losses with independent variables, the models are estimated by using potential loss data (i.e. by adjusting for damage-reduction measures). The models are estimated for various damage components and for various individual activity groups, in both linear and double logarithmic forms. The models are also estimated by combining sample units across activity groups. Multiple correlation coefficients, adjusted for degrees

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[70] The concept of multiplier effects can be understood from simplified algebraic series $(I - A)^{-1} F = (I + A + A^2 + A^3 + + +) F$, where A_s are the input-output coefficients.

[71] The sector classifications carried out are shown in Appendix Table A5.18. It is obvious that sample size (58 in 5 groups) is too meagre to be represented in the national economy, so that the estimated multipliers may be used with some caution.

of freedom, including their significance levels (estimated F Statistic) are shown against each of the models. In fact, almost each of the estimated models, for both linear and double logarithmic form, presented in these tables are suitable for modelling flood losses. However, from different considerations, some are preferred to others for subsequent use in generating the potential damage data sets.

5.1.6.1 Results of Direct Loss Models

As in the residential sector, because of the small sample size in each individual groups of activities, the feasible step could be to contemplate proportional (to value) damages, instead of absolute damages. Not surprisingly, the proportional approach has proved infeasible in the case of commercial sectors, both for industry and business[72]. Instead, the flood loss models using absolute damages generally fit well. In almost all the models the floor space variable is found to be highly significant. This leads to the conclusion that an approach of standardising damages to per square metre might be more suitable. In fact, it might be erroneous to use per enterprise damage, as there are enormous variations in floor spaces used by units[73].

As is evident from the Tables (Tables A5.6 through to A5.17), not surprisingly, some of the models of individual groups show low coefficients of determination, demonstrating that large variability exists in the damage data. On the other hand, the single models for units pooling together across all types of enterprises ('All industries'/'All business') appear to be more stable, as these account for enterprise variations in addition to other variations. Furthermore, given the larger sample size (hence larger degrees of freedom) for such models on pooled data, the coefficients of determination in all the cases are found to be highly significant (at more than 99% level).

In most of the cases of individual industries/business models, the regression coefficients are

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[72] Unlike in the residential sector, multiple correlation coefficients for proportional damages in commercial sectors are generally found to be insignificant, presumably because not all damages items (e.g. machinery, stock) in the sectors are equally susceptible to water.

[73] For example, the standard deviation of ground floor space in industries group 2 (Cotton & textiles) is estimated as 829, which is about 55 times larger than the standard deviation (15) of group 4 (Engineering & electrical) (Table A5.3).

found to be statistically significant with expected signs[74]. In almost all the cases, in both industries and business, the double-logarithmic form of models show higher correlation coefficients, implying more explanatory power of the models. For structural damages, it is assumed that no measures are undertaken to reduce such damages so that actual and potential damages are equal. For the assessment of potential damages to components such as stock or machinery, damage-reducing activities are taken into account.

Unlike in the household sector, the model results reveal that in the commercial sectors, structural damages are related to depths or durations. On the other hand, unlike in the household sector, proportional damages (to values) are generally not found to demonstrate significant relationships with explanatory variables. Although in the case of business enterprises, no machinery is expected to be used, some accessories and fixed assets (e.g. refrigerator, furniture) are amalgamated with building structures.

The Depth variable shows positive and significant influence in all the models, for all the damage components of both individual and combined groups in industries and business sector. The categorical Duration variable shows unexpected positive signs in a few cases of linear models (Dummy variable D1 = 0, for > 7 days; see Table 5.4). In the case of double logarithmic models the Duration variable generally shows expected signs.

5.1.6.2 Results of Indirect Loss Models

Indirect loss is generally found to be a function of depth, duration and floor space, with some exceptions in the case of models with individual groups in business and in industries. The Cobb-Douglas production function, fitted to the empirical data on capital and labour inputs, is generally found to fit extremely well, indicated by values of R^2 (Tables A5.10 and A5.11). For example, R^2 value (adjusted for degrees of freedom) for 'All industries' in the case of the main case study area is estimated as .77 and that for all the areas combined estimate as .76. In some of individual industries groups, R^2 values are as high as up to .90. For business enterprises also R^2 values are found to be highly significant, except for a few cases. However, the regression models for estimating Reduction Factors (to total capital) generally are not found to show a good fit (Tables A5.12 and A5.13). Over and above, the signs of

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[74] The significance levels for the regression coefficients are not shown in the tables, as in most of the cases these are found to be significant at more than 95% levels. The significance levels (P) for only R^2s are shown.

the coefficients for some explanatory variables are not as expected or statistically significant. The major reason for this could be perhaps that once machinery/equipment and stock (the principal component of capital) are inundated and damaged, further damages usually are not proportional to depths or durations. In business, the coefficient for Duration is either insignificant, or the signs are unexpected. This could be explained in that proportional damages to merchandises (e.g. cement) add little with the increase in duration once these are flooded.

Despite that the Cobb-Douglas production functions fit extremely well, and the assumption of constant labour inputs (as there are few deaths in a river flood) is valid, the field survey suggests that there is considerable disruption to labour inputs in the town under study that contains mostly small and medium-sized industries, where generally the incidence of casual and temporary workers is high.

Indirect loss is related to direct damage in almost all the models[75]. The explanatory powers of the these models (indicated by higher R^2 values) are relatively higher than those of the models regressed on depths, durations and floor space. It can be argued that indirect impacts (caused by interruption and disruption of economic activities) are not the effect of direct contact of water. Logically, thus, the indirect impacts are functions of direct losses[76].

Although the first two indirect loss models can also be used, the third model - the modelling of indirect losses through regressing on direct losses, illustrating higher explanatory powers, is considered more suitable.

5.1.6.3 Results of Multiplier Effects

The output multipliers, used for the assessment of linkage effects, are constructed for five broad groups of industries under study (Table 5.5). The sector classification of industries is shown in Appendix Table A5.18.

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[75] The variables, Depth and Duration, are not included in this model mainly because of the potential presence of multicollinearity with Direct Damage.

[76] This corroborates with the findings of the research such as Lautenbach (1957), which studied the insurance loss claims made by an American steel company, and established a strong relationship between the firms' business interruption costs (indirect losses) and property damage (direct loss) (Green et a 1983).

Table 5.5: Estimated output multipliers for groups of industries under investigation

Tangail : Major river flood

Industries groups	Output multipliers (MLT)	Recovery Factor (RF)	Demand (decline) Factor (DF)	TYPE 1 multiplier effects (Effect 1)	TYPE 2 multiplier effects (Effect 2)	TYPE 1 Linkage effects (% of indirect loss)	TYPE 2 Linkage effecs (% of indirect loss)
Food & agro-based	1.3825	.55	.30	.6221	1.0369	17.2	28.7
Cotton & textiles	1.7624	.34	.31	1.1632	1.7095	50.3	74.0
Timber & furniture	1.7643	.51	.22	.8645	1.2527	37.5	54.3
Engineering	1.8315	.46	.41	.9890	1.7399	44.9	79.0
Miscell & service	1.8110	.40	.36	1.0866	1.7386	48.7	77.9
ALL INDUSTRIES	1.7103	.48	.34	.8894	1.4709	36.9	61.1

Notes

: Output multipliers (MLT) are computed from national Input-Output Table;

: Demand Factor (DF) refers to decline in demand for products in the selected industries groups, estimated from field survey;

: Recovery Factor (RF) refers to recovery at national level in the industries groups, estimated from field survey;

: Type 1 multiplier effects (Effect 1) $\doteq$ MLT * (1 - RF);

: Type 2 multiplier effects (Effect 2) = MLT * [(1 - RF) + DF];

: For Recovery Factor, see Table 5.25 later in this Chapter;

: Type 1 Linkage effects = Effect 1 - (Effect 1 /MLT) * 100

: Type 2 Linkage effects = Effect 2 - (Effect 2 /MLT) * 100

The Leontief inverse matrix from which the multipliers are constructed is presented in Appendix Table A5.19[77]. The input-output flow matrix, from which the Leontief inverse matrix is carried out, is constructed based on two broad assumptions. First, each of the 39 production sectors is treated as an independent industry, and the household sub-sector is not included in the intermediate sector. In other words, the income-induced effects are not included. Secondly, import contents used by these sectors as inputs are included in the flow matrix.

Output multipliers (Multipliers - MLT, as shown in Table 5.5) for various economic sectors, estimated from the national I-O Table with fixed coefficients lead to what theoretically can be the linkage effects of flooding at the national level due to production loss at firm level. As explained in Chapter 2 (Section 2.6.6), such an approach is potentially inappropriate for mainly the two factors: demand-side factors and recovery/restoration factors. The field investigation shows that a regional economy (town economy in this case) is significantly resilient and thus an approach of assessing multipliers is required to capture this resiliency.

Additionally, the field investigation indicates that most of the industrial units experienced a fall in demand for their products in the aftermath of floods, presumably due to the loss of income or the act of diverting money to meet other consumption. This means that the two factors, Demand Factor (DF) and the Recovery Factor (RF) are to be incorporated in the assessment of linkage effects. The recoveries include the factors such as 'deferment', 'transferability' and utilisation of idle capacity especially by non-flooded firms. Hence, linkage effects, which are actually the spill-over effects of various trade adjustments, should be seen in a national and large flood perspective. Obviously, the multipliers constructed from national Input-output Table are to ignore these adjustments and recoveries. Additionally, since the research is aimed at national economic efficiency analysis, it is suggested that the multipliers so constructed from input-output table need some adjustment due to the above two factors.

The output multipliers (MLT), which are theoretical in nature, are constructed directly from

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[77] Following considerable arithmetical errors in the published document of the National I-O Table (GOB 1991), the 53 sectors Input-Output flow matrix and the corresponding coefficient matrix (not presented) had to be thoroughly corrected. The co-operation and help in this work, including running of the relevant computer programmes, provided by M Salimullah who is carrying out a PhD research on input-output analysis at Strathclyde University, is gratefully acknowledged. See Appendix Table A5.21 for the programmes.

national Input-output Table. Two types of multiplier effects are estimated (Table 5.5). Type 1 multiplier effects (Effect 1) are constructed through adjusting the multipliers (MLT) by the Recovery Factor, and the type 2 multiplier effects (Effect 2) are estimated through adjusting the multipliers by the two factors, Recovery and Demand Factor. The Demand Factor (DF) refers to decline in demand for products in the selected industries groups, estimated from field survey. The Recovery Factor (RF) refers to the recovery at the national level, estimated from field survey. Thus,

1) Type 1 multiplier effects (Effect 1) = MLT * (1 - RF); and
2) Type 2 multiplier effects (Effect 2) = MLT * [(1 - RF) + DF].

Two types of linkage effects are estimated : 1) by incorporating RF and 2) by incorporating RF and DF (Table 5.5). Thus, linkage effects are defined as

1) Type 1 Linkage effects = [MLT - 1] [(1 - RF)] * 100
= [Effect 1 - (Effect 1 /MLT)] * 100

and,

2) Type 2 Linkage effects = [MLT - 1] [(1 - RF) + DF] * 100
= [Effect 2 - (Effect 2 /MLT)] * 100

The present study contemplates the Type 2 linkage effects in the construction of potential damage data sets and the computation of Expected Annual Damage (carried out in Chapter 7). It needs mention here that the output multipliers constructed in this analysis are likely to have been underestimated (especially for food and agro-based industries), as in the national flow matrix some of the sector flows (e.g. rice and wheat) include flows for both production and intermediate use.

5.1.7 Construction of Flood Loss Data Sets

A variety of methods and models are examined for generating damage data sets at disaggregated levels of depths and durations. Actual damages and potential damages (adjusted to damage-reducing activities), both in absolute and proportional terms are contemplated. Five broad damage components are distinguished: (1) Structural damage (2) Machinery and Equipment damage (3) Stock damage (4) Production (primary indirect) loss and (5) Linkage effects.

The damage data sets are constructed at levels of 5 depths (e.g. 0.30m, 0.61m, 0.91m, 1.22m and 1.52m) and 2 generalised duration categories (up to 7 days and above 7 days). For reasons explained earlier, the models for 'All industries/All business' group in double logarithmic from are used for the construction.

Tables 5.6 through to 5.13 present the damage data sets for industries/business by five major damage components, disaggregated at 5 levels of depths and 2 levels of durations. The average data sets are generated at levels: (1) per industry/business damages by individual industry/business groups, and (2) per square metre of floor space by individual industry/business groups. 'Per square metre' damage data sets are constructed from 'per enterprise' data. It could be ideal to regress per square metre damages. However, as in the residential sector, per square metre damages regressed on explanatory variables show no significant relationships. Not all the coefficients are found to be significant. Moreover, not all the signs of the coefficients are found as expected. Figures A5.5 through to A5.10 are presented to show depth-damage curves for various damage components and sectors.

The potential damage data sets are generated in terms of individual sub-sectors and the whole sector. The various data sets can be used as per appraisal needs and according to basic information available (e.g. floor space or number of properties in the area under appraisal). For a more generalised use (e.g. desk-level appraisal) the sector average can be used, while for a more refined level, per enterprise or per square metre damage data set can be used. Per enterprise data set should, however, be used with some caution, as the presence of a few extreme values (e.g. capital, output and, more importantly, damage values) in the industry group 1 (food & agro-based) and industry group 2 (cotton textiles) is likely to have distorted the damage data sets to some extent. However, per square metre damage data are reasonably suitable for refined level appraisals.

The data sets are limited to use in river flooding only. Considerable improvement to the quality level of the data sets is feasible by including cross-sectional data combining all the three study areas. But as the different study areas represent different floods and the ultimate goal is to perform appraisals of the main case study area, the study has generated 'average' data sets, specific only to the main case study area. In other words, in the absence of cross-sectional data, the generated data sets suffer from a wider applicability. One other point is to be made with regards to the data sets over the structure of industries. As mentioned earlier, a striking feature of the structure of industries is that especially in a secondary town, industries-related service jobs constitute a considerable part. Ideally, thus production and service industries should have been treated separately, but as there are only a few units which are exclusively service or production units, this is not contemplated.

Clean-up Costs

The study reveals that, as in the residential sector, clean-up costs in commercial sectors are not considerable in Bangladesh. The major reason for this is that, in Bangladesh, the clean-up costs are not generally counted by enterprises as a separate damage component. The clean-up jobs are largely accomplished by permanent workers, who are, unless piece-rated, more often than not paid any way in the case of short closures[78]. Hence, clean-up costs as a separate damage component are not relevant in Bangladesh. This is also because such costs are often confused with the repair work of floor damage and it appears that respondents find it difficult to separate such costs, if any, from the costs of the repair work. Thus the research suggests that clean-up costs, treated as direct losses in this analysis, should not be dealt with separately. Such costs, if any, are amalgamated with structural damages.

5.1.8 Summary

The preceding section discusses the practical problems associated with the assessment of flood loss potentials in commercial sectors and thus evaluates the suitability of available assessment methods in Bangladesh. There appears to be no alternative to assessing commercial flood losses through interview methods based on actual flood events in Bangladesh. Nonetheless, following wide diversities in commercial activities and large variabilities in damages, the data 'arithmetically averaged' (e.g. UK approach) from the actual interview survey can hardly lead to consistent stage/damage functions. The study prescribes the need to adopt an alternative method-the 'regression' approach that can lead to fairly a consistent data sets at disaggregated levels of depths and durations.

The analysis is followed by constructing 'average' potential loss data sets for the commercial sectors through use of flood loss models.

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[78] The field survey demonstrates that only 10% of the total person-days employed in clean-up job is carried out by hired workers.

Table 5.6: Per industry estimated potential damage to firm by damage components at various depths: (Tangail study area)

Duration = up to 7 days Value in 1992-93 Taka : £ = 65 Taka(app)

Industry type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and agro-based					
: Structure	6309	9852	12665	15225	17479
: Machinery	15156	21243	25695	29541	32797
: Stock	24361	38160	49144	59156	67978
: P Indirect	35830	51804	63834	74421	83526
: Linkage effects	10391	15023	18512	21582	24223
: TOTAL	92047	136082	169850	199925	226003
Cotton and textiles					
: Structure	7077	11052	14208	17081	19609
: Machinery	18032	26534	32096	36900	40967
: Stock	49163	77012	99176	119384	131788
: P Indirect	111293	162166	200671	234677	263952
: Linkage effects	82357	120003	148497	173661	195324
: TOTAL	267922	396767	494648	581703	651646
Timber & furniture					
: Structure	1773	2768	3559	4278	4911
: Machinery	2294	3216	3890	4472	4965
: Stock	13685	20466	26356	31726	36457
: P Indirect	15686	23115	28776	33796	38131
: Linkage effects	8470	12482	15539	18250	20591
: TOTAL	41903	62047	78120	92522	105055
Engineering & electrical					
: Structure	757	1182	1519	1827	2097
: Machinery	4139	5801	7017	8067	8956
: Stock	3556	5571	7174	8636	9923
: P Indirect	14151	20145	25612	28519	31854
: Linkage effects	11179	15915	20233	22530	25165
: TOTAL	33782	48614	61555	69579	77995
Miscellaneous & service					
: Structure	1378	2152	2766	3326	3218
: Machinery	5355	7505	9078	10437	11587
: Stock	7805	12226	15745	18952	21779
: P Indirect	14638	21089	25937	30199	33856
: Linkage effects	11418	16449	20231	23555	26408
: TOTAL	410594	59421	73757	86469	96848
Sector average					
: Structure	3459	5401	6943	8347	9583
: Machinery	9175	12860	15555	17883	19855
: Stock	19590	30687	39520	47571	54665
: P Indirect	38320	55664	68766	80323	90265
: Linkage effects	23375	33955	41947	48997	55062
: TOTAL	93919	138567	172731	203121	229430

Note : Figures are rounded off to next integers

Table 5.7: Per <u>industry</u> estimated potential damage to firm by damage components at various depths (Tangail study area)

Duration > 7 days — Value in 1992-93 Taka : £ = 65 Taka(app)

Industry type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and agro-based					
: Structure	7190	11228	14435	17353	19921
: Machinery	20756	29091	35188	40455	44914
: Stock	32314	50618	65187	78468	90169
: P Indirect	45752	66065	81350	94802	106353
: Linkage effects	13262	19159	23592	27493	30842
: TOTAL	119268	176161	219752	258571	292199
Cotton and textiles					
: Structure	8066	12596	16194	19467	22349
: Machinery	25926	36337	43953	50532	56101
: Stock	65212	102152	131555	158356	181972
: P Indirect	142570	207557	256718	300120	337477
: Linkage effects	105502	153592	189971	222089	249733
: TOTAL	347276	512234	638391	750564	847632
Timber & furniture					
: Structure	2020	3155	4056	4876	5598
: Machinery	3142	4404	5327	6124	6799
: Stock	17330	27147	34960	42083	48358
: P Indirect	20001	29460	36665	43053	48568
: Linkage effects	10801	15908	19799	23249	26227
: TOTAL	53294	80074	100807	119385	135550
Engineering & electrical					
: Structure	863	1347	1732	2082	2390
: Machinery	5668	7944	9609	11048	12265
: Stock	4717	7389	9516	11455	13163
: P Indirect	18263	25964	31697	36708	40990
: Linkage effects	14428	20512	25041	28999	32382
: TOTAL	43939	63156	77595	90292	101190
Miscellaneous & service					
: Structure	1571	2453	3153	3790	4351
: Machinery	7333	10278	12432	14293	15868
: Stock	10352	16217	20884	25139	28888
: P Indirect	18814	27073	33275	38724	43399
: Linkage effects	14675	21117	25955	30205	33851
: TOTAL	52745	77138	95699	112151	126357
Sector average					
: Structure	3942	6156	7914	9514	10922
: Machinery	12565	17611	21302	24490	27190
: Stock	25985	40705	52421	63100	72510
: P Indirect	49081	71224	87941	102682	115357
: Linkage effects	29939	43447	53644	62636	70368
: TOTAL	121512	179143	223222	262422	296347

Table 5.8: Per business unit estimated potential damage to firm by damage components at various depths(Tangail study area)

Duration = up to 7 days Value in 1992-93 Taka : £ = 65 Taka(app)

Industry type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.53
Food and grocery					
: Structure	1225	1495	1672	1815	1931
: Stock	26539	43566	57606	70697	82427
: Indirect	18061	24535	29183	33151	36481
: TOTAL	45825	69596	88461	105663	120839
Cloth & footwear					
: Structure	3311	4040	4519	4906	5218
: Stock	21897	35946	47531	58333	68011
: Indirect	15543	20810	24587	27810	30514
: TOTAL	40751	60796	76637	91049	103743
Drugs & chemical					
: Structure	4395	5362	5998	6511	6925
: Stock	142002	233107	308234	387279	441042
: Indirect	32691	44512	53000	60246	66328
: TOTAL	179088	282981	367232	445036	514295
Electrical & electronics					
: Structure	3874	4727	5287	5740	6105
: Stock	35785	58744	77677	95328	111145
: Indirect	62044	83540	98964	112126	123170
: TOTAL	101703	147011	181928	213194	240420
Motor/cycle parts					
: Structure	2206	2691	3011	3268	3476
: Stock	24100	39561	52311	64199	74851
: Indirect	22978	31010	36774	41694	45822
: TOTAL	49284	73262	92096	109161	124149
Construction materials					
: Structure	1481	1806	2020	2194	2333
: Stock	8482	13924	18412	22596	26345
: Indirect	27181	36287	42815	48384	53056
: TOTAL	37144	52017	63247	73174	81734
Miscellaneous					
: Structure	3085	3764	4210	4571	4861
: Stock	5952	9771	12919	15855	18486
: Indirect	19287	24901	2803	32307	35158
: TOTAL	28324	38436	46002	52733	58505
Sector average					
: Structure	2797	3412	3817	4142	4407
: Stock	37822	62089	82099	106684	117473
: Indirect	28255	37942	44890	44890	55790
: TOTAL	68874	103443	130806	155716	177670

Note : Figures are rounded off to next integers.

Table 5.9: Per business unit estimated potential damage to firm by damage components at various depths (Tangail study area)

Duration > 7 days Value in 1992-93 Taka : £ = 65 Taka(app)

Industry type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and grocery					
: Structure	1343	1638	1833	1990	2116
: Stock	30157	49505	65460	80335	93664
: Indirect	19563	26581	31620	35922	39532
: TOTAL	51063	77724	98913	118247	135312
Cloth & footwear					
: Structure	3629	4428	4953	5377	5719
: Stock	24883	40847	54011	63285	77283
: Indirect	16802	22511	26606	30099	33031
: TOTAL	45314	67786	85570	101761	116033
Drugs & chemical					
: Structure	4817	5877	6574	7137	7590
: Stock	161360	264886	350255	429848	501168
: Indirect	35420	48236	57439	65295	71888
: TOTAL	201597	318999	414268	502280	580646
Electrical & electronics					
: Structure	4246	5181	5795	6291	6691
: Stock	40664	66753	88266	108324	126297
: Indirect	67121	90423	107143	121413	133386
: TOTAL	112031	162357	201204	236028	266374
Motor/cycle parts					
: Structure	2418	2950	3300	3582	3810
: Stock	27385	44954	59443	72951	85055
: Indirect	24866	33573	39822	45155	49631
: TOTAL	54669	81477	102565	121688	138496
Construction materials					
: Structure	1623	1980	2215	2404	2557
: Stock	9639	15823	20922	25676	29937
: Indirect	29371	39241	46318	52354	57419
: TOTAL	40633	57044	69455	80434	89913
Miscellaneous					
: Structure	3381	4125	4615	5010	5328
: Stock	6763	11103	14681	18017	21006
: Indirect	20750	26830	31164	34852	37940
: TOTAL	30894	42058	50460	57879	64274
Sector average					
: Structure	3065	3740	4183	4542	4830
: Stock	42979	70553	93291	114490	133487
: Indirect	30556	41056	44587	55013	60404
: TOTAL	76600	115349	146061	174045	198721

Note : Figures are rounded off to next integers

Table 5.10: Per square metre estimated potential damage to firm by damage components at various depths: Industries (Tangail study area)

Duration= up to 7 days Value in 1992-93 Taka : £ = 65 Taka(app)

Industry type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and agro-based					
: Structure	54	84	109	131	150
: Machinery	130	182	220	253	281
: Stock	209	327	421	507	583
: P Indirect	307	444	547	638	716
: Linkage effects	89	129	159	185	208
: TOTAL	789	1166	1456	1714	1938
Cotton and textiles					
: Structure	24	37	48	58	66
: Machinery	64	90	108	125	138
: Stock	166	260	335	403	463
: P Indirect	376	547	677	792	891
: Linkage effects	278	405	501	586	659
: TOTAL	908	1339	1669	1964	2217
Timber & furniture					
: Structure	46	72	93	112	128
: Machinery	60	84	102	117	130
: Stock	341	535	688	829	952
: P Indirect	410	604	752	883	996
: Linkage effects	221	326	406	477	538
: TOTAL	1078	1621	2041	2418	2744
Engineering & electrical					
: Structure	38	60	77	93	106
: Machinery	210	294	356	409	454
: Stock	180	282	363	438	503
: P Indirect	717	1021	1247	1445	1614
: Linkage effects	566	807	985	1142	1275
: TOTAL	1711	2464	3028	3527	3952
Miscellaneous & service					
: Structure	25	39	50	60	69
: Machinery	97	136	164	189	210
: Stock	141	221	285	343	394
: P Indirect	265	382	470	547	613
: Linkage effects	207	298	367	427	478
: TOTAL	735	1076	1336	1566	1764
Sector average					
: Structure	38	59	75	91	104
: Machinery	112	157	190	218	243
: Stock	207	325	418	504	579
: P Indirect	415	599	738	861	966
: Linkage effects	253	365	450	525	589
: TOTAL	1025	1505	1871	2199	2481

Table 5.11: Per square metre estimated potential damage to firm by damage components at various depths: Industries (Tangail study area)

Duration > 7 days

Value in 1992-93 Taka : £ = 65 Taka(app)

Industry type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and agro-based					
: Structure	62	96	124	149	171
: Machinery	178	249	302	347	385
: Stock	277	434	559	672	773
: P Indirect	392	566	697	812	911
: Linkage effects	114	164	202	235	264
: TOTAL	1023	1509	1884	2215	2504
Cotton and textiles					
: Structure	27	43	55	66	75
: Machinery	88	123	148	171	189
: Stock	220	345	444	534	614
: P Indirect	481	700	866	1013	1139
: Linkage effects	356	518	641	750	843
: TOTAL	1172	1729	2154	2534	2860
Timber & furniture					
: Structure	53	82	106	127	146
: Machinery	82	115	139	160	178
: Stock	453	709	913	1099	1263
: P Indirect	522	769	958	1124	1268
: Linkage effects	282	415	517	593	685
: TOTAL	1392	2090	2633	3103	3540
Engineering & electrical					
: Structure	44	68	88	106	121
: Machinery	287	402	487	560	621
: Stock	239	374	482	580	667
: P Indirect	925	1315	1606	1860	2077
: Linkage effects	731	1039	1269	1469	1641
: TOTAL	2226	3198	3932	4575	5127
Miscellaneous & service					
: Structure	28	44	57	69	79
: Machinery	133	186	225	259	287
: Stock	187	294	378	455	523
: P Indirect	341	490	602	701	786
: Linkage effects	266	382	470	547	613
: TOTAL	955	1396	1732	2031	2288
Sector average					
: Structure	43	67	86	103	118
: Machinery	154	215	260	299	332
: Stock	275	431	555	668	768
: P Indirect	532	768	946	1102	1236
: Linkage effects	325	468	577	407	754
: TOTAL	1329	1949	2424	2579	3208

Table 5.12: Per square metre estimated potential damage to firm by damage components at various depths : <u>Business</u> (Tangail study area)

Duration = up to 7 days | Value in 1992-93 Taka : £ = 65 Taka(app)

Business type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and grocery					
: Structure	63	76	85	93	98
: Stock	1354	2223	2939	3607	4205
: Indirect	921	1252	1489	1691	1861
: TOTAL	2338	3551	4513	5391	6164
Cloth & footwear					
: Structure	137	167	187	203	216
: Stock	908	1490	1971	2418	2820
: Indirect	644	863	1019	1153	1265
: TOTAL	1689	2520	3177	3774	4301
Drugs & chemical					
: Structure	104	127	142	154	163
: Stock	3351	5500	7273	8916	10407
: Indirect	771	1050	1251	1422	1565
: TOTAL	4226	6677	8666	10502	12135
Electrical & electronics					
: Structure	223	272	305	331	352
: Stock	2063	3386	4477	5494	6406
: Indirect	3576	4815	5704	6463	7099
: TOTAL	5262	8473	10486	12288	13857
Motor/cycle parts	160	195			
: Structure	1743	2861	218	236	251
: Stock	1661	2242	3782	4642	5412
: Indirect			2659	3015	3313
: TOTAL	3564	5298	6659	7893	8976
Construction materials					
: Structure	49	60	67	73	78
: Stock	283	465	615	754	880
: Indirect	908	1212	1430	1616	1771
: TOTAL	1240	1737	2112	2443	2729
Miscellaneous					
: Structure	161	197	220	239	254
: Stock	311	510	675	828	965
: Indirect	1007	1300	1509	1687	1836
: TOTAL	1479	2007	2404	2754	3055
Sector average					
: Structure	128	156	175	190	202
: Stock	1430	2348	3105	3810	4442
: Indirect	1356	1819	2152	2435	2673
: TOTAL	2914	4323	5032	6435	7317

Table 5.13: Per square metre estimated potential damage to firm by damage components at various depths : Business (Tangail study area)

Duration > 7 days   Value in 1992-93 Taka : £ = 65 Taka(app)

Business type /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Food and grocery					
: Structure	69	84	94	102	108
: Stock	1539	2526	3340	4099	4779
: Indirect	998	1356	1613	1833	2017
: TOTAL	2606	3966	5047	6034	6904
Cloth & footwear					
: Structure	150	184	205	223	237
: Stock	1032	1693	2239	2748	3204
: Indirect	697	933	1103	1248	1369
: TOTAL	1879	2810	3547	4219	4810
Drugs & chemical					
: Structure	114	139	155	168	179
: Stock	3807	6250	8265	10143	11826
: Indirect	836	1138	1355	1541	1696
: TOTAL	4757	7527	9775	11852	13701
Electrical & electronics					
: Structure	245	299	334	363	386
: Stock	2344	3847	5087	6243	7279
: Indirect	3869	5212	6175	6998	7688
: TOTAL	6458	9358	11596	13604	15353
Motor/cycle parts					
: Structure	175	213	239	259	275
: Stock	1980	3251	4298	5275	6150
: Indirect	1798	2428	2879	3265	3589
: TOTAL	3953	5892	7416	8779	10014
Construction materials					
: Structure	54	66	74	80	85
: Stock	322	528	699	857	1000
: Indirect	981	1310	1546	1748	1917
: TOTAL	1358	1904	2319	2685	3002
Miscellaneous					
: Structure	177	215	241	262	278
: Stock	353	580	767	941	1097
: Indirect	1084	1401	1627	1820	1981
: TOTAL	1614	2196	2635	3023	3356
Sector average					
: Structure	140	171	192	208	221
: Stock	1625	2668	3527	4329	5048
: Indirect	1466	1966	2329	2635	2894
: TOTAL	3231	4805	6048	7172	8163

5.2 Revealing of Impacts

5.2.1 Introduction

This section is an empirical analysis examining flood damages in relation to various flood variables. The section widens the empirical base for conclusions relating to revealing of impacts and their variations among the flood type, activity type, size, structure and capital intensity. The two major commercial sectors, industries and business, are dealt with separately in the analysis. In most of the analysis, the three urban areas representing three different flood types are considered separately.

5.2.2 Flood Type and Activity Type Variations

In order to have a deeper insight into various socio-economic aspects of floods and their impacts, it would be interesting to first provide a representation of salient features of the three floods and the pertinent floodplain users. Tables 5.14 and 5.15 represent such information for industries and business land users respectively. Flood impacts are analysed in relation to three flood types: major river flood, flash flood and tidal flood, and according to type of commercial activities. Tables 5.16 through to 5.18 present per enterprise industrial mean damages for the three different floods by industries type. Tables 5.19 through to 5.21 present the similar information for business enterprises. The standard deviations are displayed against the respective damage components. Besides, the contribution of the individual components to total damages are shown in the tables.

The tables generally manifest, for both industries and business, enormous variations in damage figures over type of floods. The standard deviations for damages demonstrate a wide range of variations, at times estimating as much as, nearly double the mean damage values. As is evident from the tables, the extent of damages due to different types of floods are significantly different[79]. In industries the tidal flood causes nearly 4 times the damage of the river flood in industries. Per industry damage averaged over all types is in the range of 148,000 Taka in the major river flood, as against 65,000 Taka in the flash flood and 587,000 Taka in the tidal flood. In terms of the proportional damages, again, the more devastating flood types are the flash and tidal flood, which destroy about 46% and 41% of total assets

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[79] The differences in damages are also statistically significant.

Table 5.14: **Basic characteristics of three flood types and sample units under study :industries**

Characteristics	Flood type		
	Major river flood	Flash flood	Tidal flood
Urban area	Tangail	Bahubal (Habiganj)	Khatunganj (Chittagong)
Sample industries (no)	58	32	31
Length of operating (yrs)	15	9	15
Ground floor space (sq m)	103	50	269
Floor height (cm)	16	21	0
Major flood variables	Depth, Duration	Depth,Duration Velocity	Depth,Duration Velocity,Storm Salinity
Depth of flooding (m)	.66	.50	1.1
Duration of flooding (days)	18	2.6	6 hrs
Frequency of flooding	1.5	2.5	1.8
If formal warning given	No	Yes	Yes
Lead time (hrs)	-	2.6	45
Units believed warning(%)	-	25	3
Units perceived occurrence(%)	100	34	6
Perceived before (hrs)	53	1.03	0.03
Hrs between water entered town & property	22	0.60	0.1
Goods at risk(%)			
:input	48	49	73
:output	53	66	76
:machinery	48	29	51
Units moved merchandise(%)	98	88	6

Note:All figures represent averages.

Table 5.15: Basic characteristics of three flood types and sample units under study:business

Characteristics	Flood type		
	Major river flood	Flash flood	Tidal flood
Urban area	Tangail	Bahubal (Habiganj)	Khatunganj (Chittagong)
Sample business(no)	42	31	31
Length of operating (yrs)	15	8	20
Ground floor space(sq m)	23	25	69
Floor height(cm)	13	25	-2
Major flood variables	Depth, Duration	Depth,Duration Velocity	Depth,Duration Velocity,Storm Salinity
Depth of flooding(m)	.47	.59	.99
Duration of flooding(days)	14	2	5 hrs
Frequency of flooding	1.1	1	1.7
If formal warning given	No	Yes	Yes
Lead time(hrs)	-	4	35
Units believed warning(%)	-	16	3
Units perceived occurrence(%)	100	13	3
Perceived before(hrs)	79	.9	0.2
Hrs between water entered town & property	26	.6	0.3
Goods at risk(%)	40	36	51
Units moved merchandise(%)	100	77	3

Note:All figures represent averages.

Table 5.16: Composition of potential flood damages in industries (major river flood,1988: Tangail)

Value in 1992-93 TK : TK 65 = £(approx)

Industry type	Damage components	Mean Damage value [1]	S Dev	% of total damage [2]	Damage as % of asset value [3]
Food and agro-based					
	Structure	26019	38317	7.7	8.3
	Machinery	45276	86558	13.4	2.0
	Stock	79308	88416	23.5	29.7
	Primary indirect	187003	253018	55.4	134.0
	Total damage	337606	414142	100.0	12.0
Cotton & other textiles					
	Structure	8071	16704	3.9	2.4
	Machinery	28230	58041	13.5	3.9
	Stock	45066	76990	21.5	25.2
	Primary indirect	128085	227138	61.2	126.8
	Total damage	209453	367832	100.0	16.9
Timber & furniture					
	Structure	5109	4785	7.1	10.4
	Machinery	13940	16251	19.3	20.5
	Stock	22414	24907	31.1	32.0
	Primary indirect	30647	16884	42.5	157.2
	Total damage	72110	54727	100.0	38.5
Engineering & electrical					
	Structure	2240	2634	3.4	8.1
	Machinery	12712	16348	19.4	21.6
	Stock	8034	14268	12.2	24.2
	Primary indirect	42674	36859	65.0	191.0
	Total damage	65660	49477	100.0	54.9
Miscellaneous & service					
	Structure	3590	6166	4.8	4.7
	Machinery	8584	11415	11.5	11.0
	Stock	23995	39606	32.3	42.0
	Primary indirect	38210	46843	51.4	119.0
	Total damage	74379	90103	100.0	35.2
All groups					
	Structure	8522	19944	5.8	5.5
	Machinery	20656	47027	14.0	3.4
	Stock	34768	59849	23.5	30.0
	Primary indirect	83823	158009	56.7	101.4
	Total damage	147769	261046	100.0	16.9

Note : 1 Direct damages, adjusted for damage-reducing activities, and indirect damages, net of recovery,if any;
: 2 For primary indirect damage (measured in Value Added), the percentage shown of monthly Value Added;
: 3 In case of total damage, the percentage shown of total plant value.

Table 5.17: Composition of potential flood damages in industries (flash flood,1993: Bahubal)

Value in 1992-93 TK : TK 65 = £(approx)

Industry type	Damage components	Mean Damage value [1]	S Dev	% of total damage [2]	Damage as % of asset value [3]
Food and agro-based					
	Structure	4729	5165	7.8	7.6
	Machinery	12936	10617	21.2	15.5
	Stock	8600	4729	14.1	36.0
	Primary indirect	34622	46375	56.9	112.1
	Total damage	60887	59818	100.0	35.9
Cotton & other textiles					
	Structure	1200	-	6.5	2.5
	Machinery	6300	-	34.1	11.8
	Stock	8200	-	44.4	18.0
	Primary indirect	2762	-	15.0	108.3
	Total damage	18462	-	100.0	12.6
Timber & furniture					
	Structure	2358	1930	4.7	11.5
	Machinery	3047	2834	6.1	5.8
	Stock	30034	47053	60.4	36.9
	Primary indirect	14260	20791	28.7	61.1
	Total damage	49699	68202	100.0	32.2
Engineering & electrical					
	Structure	1506	544	17.9	9.0
	Machinery	3962	2792	47.1	15.9
	Stock	1039	1130	12.4	22.5
	Primary indirect	1900	1548	22.6	34.6
	Total damage	8407	4711	100.0	18.2
Miscellaneous & service					
	Structure	2633	1586	1.7	12.6
	Machinery	62136	170871	40.0	81.2
	Stock	12428	18204	8.0	9.9
	Primary indirect	78090	209481	50.3	42.2
	Total damage	155287	397900	100.0	69.6
All groups					
	Structure	2643	2811	4.1	9.0
	Machinery	20370	85042	31.5	35.9
	Stock	11200	23255	17.3	11.8
	Primary indirect	30450	106413	47.1	55.9
	Total damage	64663	201136	100.0	45.9

Note : 1 Direct damages, adjusted for damage-reducing activities, and indirect damages, net of recovery,if any.
: 2 For primary indirect damage (measured in Value Added), the percentage shown of monthly Value Added;
: 3 In case of total damage, the percentage shown of total plant value; - only one observation.

Table 5.18: Composition of potential flood damages in industries (tidal flood,1991: Khatunganj)

Value in 1992-93 TK : TK 65 = £(approx)

Industry type	Damage components	Mean Damage value [1]	S Dev	% of total damage [2]	Damage as % of asset value [3]
Food and agro-based					
	Structure	55566	43667	6.7	11.2
	Machinery	39400	29316	4.8	10.8
	Stock	442075	725608	53.5	65.4
	Primary indirect	289710	605627	35.0	209.2
	Total damage	826751	964594	100.0	53.8
Cotton & other textiles					
	Structure	40034	39552	2.1	5.0
	Machinery	29018	23759	1.5	2.8
	Stock	1737926	2920098	91.1	58.0
	Primary indirect	100296	67153	5.3	131.7
	Total damage	1907274	2997434	100.0	7.1
Timber & furniture					
	Structure	20995	14520	18.4	27.6
	Machinery	7146	7761	6.3	12.4
	Stock	62722	31794	55.0	5.4
	Primary indirect	23249	9627	20.4	189.5
	Total damage	114112	13803	100.0	44.4
Engineering & electrical					
	Structure	9971	7324	26.4	18.8
	Machinery	5403	3200	14.3	9.4
	Stock	6708	7395	17.8	13.2
	Primary indirect	15701	8152	41.6	128.8
	Total damage	37783	20503	100.0	23.4
Miscellaneous & service					
	Structure	32542	57805	11.4	5.1
	Machinery	17544	25289	6.2	8.2
	Stock	67717	115223	23.8	38.7
	Primary indirect	166755	460942	58.6	537.1
	Total damage	284558	652009	100.0	27.6
All groups					
	Structure	34707	43080	5.9	7.7
	Machinery	22014	25346	3.7	6.9
	Stock	379621	1144957	64.7	57.6
	Primary indirect	150753	407943	25.7	185.6
	Total damage	587095	1272721	100.0	41.1

Note : 1 Direct damages, adjusted for damage-reducing activities, and indirect damages, net of recovery,if any.
: 2 For primary indirect damage (measured in Value Added), the percentage shown of monthly Value Added;
: 3 In case of total damage, the percentage shown of total plant value.

Table 5.19: Composition of potential flood damages in business (major river flood,1988: Tangail)

Value in 1992-93 TK : TK 65 = £(approx)

Business group	Damage components	Mean Damage value [1]	S Dev	% of total damage [2]	Damage as % of asset value [3]
1 Food grocery and stationary					
	Structure	3596	7512	5.0	7.9
	Stock	45511	44559	63.4	38.9
	Primary indirect	22710	17853	31.6	78.5
	Total damage	71817	56837	100.0	41.2
2 Cloth and footwear					
	Structure	6282	6060	8.8	10.9
	Stock	41062	29950	57.6	17.2
	Primary indirect	23926	26364	33.6	197.7
	Total damage	71270	57335	100.0	21.8
3 Drugs and chemicals					
	Structure	6701	4184	2.2	5.6
	Stock	250753	157021	80.8	31.8
	Primary indirect	52778	46562	17.0	94.5
	Total damage	310232	188009	100.0	32.8
4 Electrical and electronics					
	Structure	6549	6220	4.2	10.7
	Stock	59882	31687	38.6	20.7
	Primary indirect	88746	98914	57.2	243.0
	Total damage	155177	135180	100.0	39.7
5 Motor/cycle parts					
	Structure	3553	2989	5.7	11.6
	Stock	35313	9202	56.4	15.0
	Primary indirect	23801	15022	38.0	93.6
	Total damage	62667	21742	100.0	18.3
6 Construction materials					
	Structure	2366	912	1.8	3.8
	Stock	20873	14630	16.1	5.1
	Primary indirect	106549	154924	82.1	264.6
	Total damage	129788	162330	100.0	26.9
7 Miscellaneous					
	Structure	4389	2326	9.3	10.0
	Stock	12714	9003	27.0	16.9
	Primary indirect	30060	35865	63.7	210.4
	Total damage	47163	43648	100.0	34.5
All groups					
	Structure	4584	4961	4.4	8.1
	Stock	59747	91076	56.8	23.0
	Primary indirect	40870	17852	38.8	107.6
	Total damage	105201	120693	100.0	30.5

Note : 1 Direct damages, adjusted for damage-reducing activities, and indirect damages, net of recovery,if any

: 2 For primary indirect damage (measured in Gross Margin), the percentage shown of monthly Gross Margin

: 3 In case of total damage, the percentage shown of total plant value.

: Structural damage includes equipment/furniture damage.

Table 5.20: Composition of potential flood damages in business (flash flood,1992: Bahubal)

Value in 1992-93 TK : TK 65 = £(approx)

Business group	Damage components	Mean damage value [1]	S Dev	% of total damage [2]	Damage as % of asset value [3]
1 Food grocery and stationary					
	Structure	2196	1911	3.9	2.9
	Stock	23375	16444	41.9	29.2
	Primary indirect	30278	53878	54.2	188.8
	Total damage	55849	59149	100.0	34.5
2 Cloth and footwear					
	Structure	1163	832	4.4	4.5
	Stock	11875	12168	44.7	7.7
	Primary indirect	13530	11551	50.9	225.5
	Total damage	26568	13103	100.0	14.1
3 Drugs and chemicals					
	Structure	3053	2637	7.5	6.6
	Stock	30750	17765	75.8	32.4
	Primary indirect	6769	6508	16.7	82.0
	Total damage	40572	25534	100.0	27.2
4 Electrical and electronics					
	Structure	-	-	-	-
	Stock	-	-	-	-
	Primary indirect	-	-	-	-
	Total damage	-	-	-	-
5 Motor/cycle parts					
	Structure	8575	10925	56.3	38.1
	Stock	5000	2828	32.8	13.3
	Primary indirect	1669	344	10.9	37.1
	Total damage	15244	7752	100.0	23.0
6 Construction materials					
	Structure	3386	5010	9.1	4.3
	Stock	28520	25049	76.3	22.5
	Primary indirect	5475	3917	14.6	43.9
	Total damage	37381	32603	100.0	17.8
7 Miscellaneous					
	Structure	1913	1939	10.1	8.2
	Stock	13375	9860	69.7	26.1
	Primary indirect	3889	1710	20.3	72.0
	Total damage	19177	11786	100.0	24.6
All groups					
	Structure	2740	3563	6.9	4.9
	Stock	21197	17303	53.3	22.9
	Primary indirect	15813	35059	39.8	138.6
	Total damage	39750	41791	100.0	25.7

Note : 1 Direct damages, adjusted for damage-reducing activities, and indirect damages, net of recovery,if any
: 2 For primary indirect damage (measured in Gross Margin), the percentage shown of monthly Gross Margin
: 3 In case of total damage, the percentage shown of total plant value
: Structural damage includes equipment/furniture damage.

Table 5.21: Composition of potential flood damages in business (tidal flood,1991: Khatunganj

Value in 1992-93 TK : TK 65 = £(approx)

Business group	Damage components	Mean damage value [1]	S Dev	% of total damage [2]	Damage as % of asset value [3]
1 Food grocery and stationary					
	Structure	38603	34423	11.6	25.6
	Stock	147115	153320	44.1	40.8
	Primary indirect	148246	231477	44.4	168.4
	Total damage	333964	352513	100.0	63.3
2 Cloth and footwear					
	Structure	24266	24312	13.3	35.2
	Stock	62722	37691	34.3	25.7
	Primary indirect	96120	138566	52.5	160.0
	Total damage	183108	199480	100.0	54.4
3 Drugs and chemicals					
	Structure	17175	15869	6.3	16.6
	Stock	189909	205138	69.7	34.1
	Primary indirect	65336	55662	24.0	250.0
	Total damage	272420	246687	100.0	39.5
4 Electrical and electronics					
	Structure	523	-	1.4	1.0
	Stock	31361	-	81.7	36.6
	Primary indirect	6523	-	17.0	120.0
	Total damage	38407		100.0	23.9
5 Motor/cycle parts					
	Structure	66047	-	31.2	80.3
	Stock	104537	-	49.5	50.0
	Primary indirect	40769	-	19.3	325.0
	Total damage	211353	-	100.0	72.5
6 Construction materials					
	Structure	19352	18516	12.7	12.4
	Stock	73176	55970	48.1	23.8
	Primary indirect	59746	81083	39.2	150.4
	Total damage	152274	96287	100.0	31.4
7 Miscellaneous					
	Structure	8274	9635	9.2	13.4
	Stock	54011	49678	60.5	29.8
	Primary indirect	27017	27419	30.3	287.2
	Total damage	89302	85520	100.0	35.9
All groups					
	Structure	29067	29484	11.6	23.5
	Stock	118510	130758	47.4	36.0
	Primary indirect	102513	175091	41.0	148.3
	Total damage	250090	279539	100.0	53.1

Note : 1 Direct damages, adjusted for damage-reducing activities, and indirect damages, net of recovery,if any

: 2 For primary indirect damage (measured in Gross Margin), the percentage shown of monthly Gross Margin

: 3 In case of total damage, the percentage shown of total plant value;

: Structural damage includes equipment/furniture damage; - = one observation.

respectively. Despite the fact that the major river flood has a much longer duration, the flood damage accounts for 17% of the total value of assets.

In business enterprises, again, the tidal flood is the most destructive. However, the damages are lower, compared to those in the industries. An average business unit suffers damages to the tune of 105,000, 40,000 and 250,000 Taka in the major river, flash and tidal flood respectively. In proportional (to value) terms, the damages in the three floods are estimated as 31%, 26% and 53% respectively.

Among the direct damages, stock is the most severe damage component in the case of all the flood types. In industries, this accounts for 24%, 17% and 65% in the total damage in the river, flash and tidal flood respectively. In business units, stock damage comprises 57%, 53% and 47% of the total damage in the three floods respectively.

Considered of all the damage components, direct and indirect, indirect damage generally constitutes the major part in the total damages, accounting for 57%, 47% and 26% in industries in the three floods respectively. In business units the contributions are 39, 40 and 41 per cent in total damage in the three floods respectively.

The tables demonstrate a wide variations in damages among different types of industrial and business units. Engineering and electrical, food and agro-based, and timber and furniture units are generally the more affected group of industries. In terms of plants' asset value, damage to engineering and electrical type is the highest (55%) followed by 39% in timber and furniture units in the river flood. In the flash flood, miscellaneous and service industries suffer most (70%) followed by food and agro-based industries suffering 36% of their total asset value. In the tidal flood, food and agro-based units are the most affected in terms of asset value (54%), followed by timber and furniture units (44%). So far as business enterprises are concerned, generally the food & grocery, electrical & electronics, and motor & cycle parts units suffer more.

5.2.3 Explaining Damage Variations

The wide variations (both in absolute and proportional terms) in flood impacts among various commercial enterprises suggest that flood impacts would be the product of social, structural and economic factors.

Table A5.22 (Appendix Section) present some tests of associations (e.g. Chi square-X^2 test), providing some useful insights as to whether the selected variables (dependent variables) are related to the independent variable, industry/business activities. The dependent variables consist of both physical and flood variables.

From among numerous tests of associations undertaken, some of the revealing results are presented in the table. As the results are self-explanatory, only a few main points are outlined in this section. As is evident from Table A5.22, very few X^2 values, particularly for physical variables, are found to be statistically significant[80]. In other words, the commercial enterprises are not generally considerably different in relation to host of variables, which are expected. The variables for which the association with types of enterprise are insignificant (for most of the areas/flood types) include, years of running business, ceiling space, threshold-depth and threshold-duration, depth, duration and frequency of flooding. Distances of properties from the nearest flood water (measured in terms of time taken between water entered town and one's property) are also found to be unrelated to types of enterprises, which is expected as industrial or business units generally cluster around particular locations. Likewise, the variables such as lead time, recovery time and perception of occurrence of floods show no significant relationship with types of commercial activities.

Some analyses are carried out in order to examine associations among selected damage and explanatory variables. The labels of these selected variables are presented in Table A5.23 (Appendix Section). Tables A5.24 and A5.25 are presented to show the results of X^2 associations for industries and business respectively. Additionally, Pearson's correlations among the same set of variables are estimated to find the direction and strength of the relationships, which are presented in Appendix Tables A5.26 through to A5.31.

The tables delineate aspects of complex interactions of damageability of commercial properties. A few general points are made at this stage. The tables of X^2 associations (Tables A5.24 and A5.25) demonstrate that many of the results of associations among the three study areas are incompatible, presumably because of the three different flood characteristics.

However, structural damages are generally related to floor space of the properties and value

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[80] The 95% confidence level is considered as an acceptable significance level.

of buildings, which is expected. Likewise, the variables such as actual and potential damages to machinery/equipment, and damages averted (by measures) are generally associated with the value of machinery/equipment in the case of industries. Actual and potential damage to stock are evidently associated to their values in the case of both industries and business in all the study areas. The damage to stock avoided by removal in industries is generally associated with the area of ceiling space, which is postulated, as larger the area of ceiling space more feasible are for the inventories to be removed.

The tables of correlations coefficients (Tables A5.26 through A5.31, Appendix Section), which are again self-explanatory, depict that absolute damages are generally found to be positively related to values of the properties (buildings, machinery and stock) in the case of both industries and business for all the study areas. In other words, higher-value properties have the tendency to have higher structural, stock and stock damages, which is expected. For example, for industries, the correlation coefficients (denoted by r, significance denoted by *) of absolute structural damages with value of building are found to be r=.64* and r=.77* in the case of the river and tidal flood respectively.

Generally absolute damages are not directly related to depths or durations. Instead, the proportional (to values) damages, are found to be directly related to depths and durations in a few cases. For instance, r=.24 and r=.48* for proportional structural damages (DAMPROP1) with depths and durations respectively, in the case of industries in the river flood. The latter is significant but the former is not.

Production loss, in terms of value added/gross margin, shows positive relationships with depths and durations, but very few of them are statistically valid. This is quite understandable in that production loss is likely to be a direct function of direct loss (e.g. to machinery, stock) rather than to depths or durations of flooding. Floor spaces (AREA) are found to be positively related to both actual and potential damage, for structure, machinery and stock damage in the case of both industries and business in the river and tidal flood.

The variable, total employment (EMPL), is found to be positively and directly related to value of machinery/equipment moved (MOVE1) or value of stock moved (MOVE2) (r=.54* and .76* respectively, for industries in the river flood area). Similar relationships are established with DAMAVOD1 (Damage to machinery/equipment avoided by removal) and DAMAVOD2 (Damage to stock avoided by removal). This is expected as, presumably, employed workforce play a vital role in the damage reduction activities through removal of stock and other materials[81].

In aggregate, the analysis reveals that damages are generally associated with their values. In other words, higher-value properties have the tendency to have higher structural and stock damages. Production loss is found to be a direct function of direct loss, rather than to depth or duration of flooding. Floor spaces, by and large, are positively related to damages. The human factor, labour force employed, is found to be positively and directly related to both value of goods moved and value of damages avoided by removal.

It is difficult to concretely explain damage variations in that the interactions among damage and explanatory variables are complex and multi-dimensional. The warning lead time, differential perception powers of property owners, and the distance of properties from rivers are among the factors likely to contribute to damage variations. As can be recalled from the previous chapter on residential sector, there is clear evidence that warnings and perceptions are inversely related to damages. In the commercial sectors, however, the analysis (not presented) shows that the relationship is not as clear as that. Several reasons can perhaps explain this. First, few property owners in commercial sectors believed the message of warning in the event of flash and tidal flood. Secondly, commercial goods/stock are bulky and voluminous that are difficult to move, compared to relatively handy items in the residential sector. Thirdly (and, perhaps, the most important), some could not adopt any immediate measures mainly due to infrastructural adversities, following among others, power failure, lack of extra workers and transport and traffic congestion in an already congested area. The adversities had worsened as the property owners did not usually stay in the respective premises at night when the disasters happened. For the above mentioned reasons, the role of warning and perception in commercial flood losses has not been contemplated.

5.2.4 Other Factors - Velocity, Storm and Salinity

Apart from inundation, the other factors contributing to damages are velocity in the case of the flash flood, and velocity, storm and salinity in the case of the tidal flood. Based on the perception of the respondents in regards to susceptibility of individual damage components,

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[81] A similar finding in the residential sector shows that the number of adult members in households has a positive impact on the damages of the contents avoided.

some crude estimates on the main effects caused by these factors are obtained. The respondents (of the flash and tidal flood area) were asked to separate (in %) their total damages to each of the three major damage components (e.g. structure, machinery and stock) on account separately of inundation, velocity, storm and salinity. The responses were obtained keeping the respective total damage to be 100. Although the interaction effects were ignored in the estimates, the field survey reveals that the respondents were able to assess the main effects of the factors. The damage contributions of the four factors in industries and business are presented in Tables A5.32 and A5.33 (Appendix Section).

It appears from Table A5.32 that, in the case of the flash flood averaged over all industry types, a little less than three-fourths of the structural damages are caused by inundation alone, and a little more than one-fourth of the damage is caused by velocity. For machinery/equipment damage in the case of the flash flood, the contributions by inundation and velocity in the total damage are estimated in the range of 83 and 17 per cent respectively. For stock, the contributions of inundation and velocity are 79 and 21 per cent respectively. Nonetheless, X^2 values for only stock (in the case of both inundation and velocity) are significant at an acceptable level of significance[82].

In the case of the tidal flood, it is revealed that for industries the storm variable, is by far the most damage contributing factor, contributing 57% to damages to structure. The factor velocity contributes in the range of 25% to the structural damage. In the case of the machinery/equipment, however, salinity contributes the highest percentages (e.g. 50%) to total damages, followed by inundation accounting for about 38% of the total damage. The contribution of storm in the machinery damage is not considerable. For stock damage inundation constitutes 52% in the total damage, followed by salinity contributing 26% and velocity contributing 17% to total damage. The contribution of storm in the stock damage is minor, estimated as 5%. Again, the X^2 values for only stock are significant, indicating association of stock damage with industry type, which is significant for all the factors, inundation, velocity, storm and salinity. In aggregate for industries, in a tidal flood the structures are found to be relatively more vulnerable to storm, and machinery/equipments to salinity. Stocks are more vulnerable to inundation. In a flash flood, keeping inundation aside, velocity contributes most to structural damage. However, total damages in the two

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[82] As not all of the enterprises responded, information on this is meagre for valid X^2 tests. X^2 values are estimated (not presented) through merging the industries/business groups; thus the associations are indicative.

types of floods are significantly different, as the damage factors are not the same and there can be host of combinations of interaction effects[83].

As for business enterprises in a flash flood, inundation is the cause of structural damage by 72%, while the remaining 28% is by velocity (Table A5.33). Inundation is the cause of stock damage by 91%, as against 9% by velocity. There appears to be no significant variations among types of business outlets in the damages caused due to the two factors. Only for the stock damage due to velocity, X^2 value is found to be significant at 8% level. In the tidal flood, like in industries, storm is the major contributor to total structural damages, by about 39%, followed by velocity by 23%. Salinity and inundation contribute to about 21% and 17% of the total structural damages respectively. In the stock damage, about 50% damage is estimated to have been caused by inundation, followed by salinity that caused about 28% of the total damage. Nevertheless, only for the stock damage caused by salinity, is the X^2 value found to be significant, indicating that there is considerable association of salinity with business activities. In aggregate in a tidal flood, keeping aside inundation, storm is the major damage factor to structures, followed by salinity and velocity as the major factors in the stock damage in business enterprises.

5.2.5 Damage Variations by Size and Structure

Table 5.22 presents analysis of flood losses in relation to size and structure of industrial and business enterprises in the main case study area. The analysis is carried out considering size both in terms of employment and capital[84]. On an average an industry suffers potential direct loss in the range of 64,000 Taka, which is about 23% of the total value of the plant. An industry suffers 230,000 Taka in output loss, which in terms of monthly output, is about 165%. As regards damages among activities according to size, larger units suffer larger amount of losses in absolute terms, which is expected. X^2 values are significant for both direct loss and output loss. The striking feature, however, is that the small-sized enterprises are generally relatively more vulnerable to floods. The Table reveals that the smaller the size

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[83] An average industry in the tidal flood suffers potential damage nearly nine times that caused by the flash flood (Table 5.17 and 5.18).

[84] The sample units include a few extreme cases and the sampling distribution towards size is skewed.

Table 5.22: Comparative analysis of flood losses by size and structure of enterprises

Industries : Tangail

	Per enterprise		Direct loss as % of plant value	Output loss as % of monthly output	% of indirect loss to nation
Enterprise by size	Direct loss (000TK)	Output loss (000TK)			
Employment					
Small (< 10)	28	79	24	168	48
Large (> 10)	166	664	21	158	53
(X^2 significance level)	(.00)	(.00)	(.62)	(.78)	(.49)
Capital					
Small (<0.1 M TK)	13	59	27	175	72
Medium (0.1 M-1.0M TK)	88	266	19	159	46
Large (> 1.0 M TK)	399	1712	6	119	51
(X^2 significance level)	(.00)	(.00)	(.02)	(.53)	(.10)
Structure					
Mainly production	88	334	24	158	52
Mainly service	25	75	21	178	64
(X^2 significance level)	(.06)	(.00)	(.12)	(.10)	(.00)
ALL INDUSTRIES	64	230	23	165	52

Business : Tangail

Capital(Total)					
Small (< 0.1 M TK)	17	66	24	155	69
Medium(0.1 - 0.3 M TK)	45	213	17	174	59
Large (> 0.3 M TK)	161	856	18	149	47
(X^2 significance level)	(.00)	(.00)	(.43)	(.93)	(.43)
Capital(Stock)					
Small (<0.1 M TK)	21	84	22	150	72
Medium(0.1 M-0.2 M TK)	53	166	19	131	62
Large (> 0.2 M TK)	129	747	17	201	47
(X^2 significance level)	(.00)	(.00)	(.05)	(.56)	(.22)
ALL BUSINESS	64	324	19	163	52

Note : Direct damage refers to potential damage

: Output loss refers to production loss in industries, and turnover loss in business the higher are the percentage of damages to their asset values[85]. This is found particularly for industries, and for both direct and output losses. For example, for industries, the proportion of direct damages (to value of plant) is estimated in the range of 24% for a small-sized (employment-wise) unit, as against 21% for a large-sized industry. A small-sized unit loses 168% of its monthly output, while a large-sized unit suffers output loss in the range of 158% of monthly output (X^2 value, however, is not statistically significant).

For units, categorised capital-wise, again, smaller units generally have higher proportion of losses. For instance, the percentage of direct loss to the value of the plant for small, medium and large-sized units (capital-wise) is estimated to be 27, 19 and 6 respectively (X^2 values significant). The corresponding figures for proportions of output loss are 175%, 159% and 119% respectively (X^2 values significant).

It is interesting to examine the flood damages according to product structure. In absolute terms, production firms suffer more than those of service-oriented ones, which is true both for direct and indirect loss (X^2 values significant). In proportional terms, output losses are higher for the latter (178% as against 158%), while direct losses are higher for the former (24% as against 21%).

In the business units by size (categorised stock-wise), the proportion of direct loss (to asset value) is estimated as 22%, 19% and 17% for a small, medium and large unit respectively, for which X^2 value is statistically significant. As regards turnover losses, however, a distinct trend is not demonstrated (X^2 value not significant).

To summarise, the study reveals that small-sized enterprises (particularly for industrial units, categorised capital-wise) tend to be more vulnerable to flood hazard. Given that this analysis relates to the major river flood, similar findings (not presented) almost hold good in the case of the other floods. This corroborates a similar finding for residential properties - that the poorest people are the most vulnerable to floods and they have the most to lose in proportional terms (Davis 1984a; 1984b; Blaikie et al 1994).

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[85] For not all the cases, however, is the difference found to be statistically significant.

5.2.6 Capital-intensity Variations

The study examines flood losses with respect to capital intensities[86]. Table 5.23 presents the level of capital intensities and flood loss potentials by type of sample industries in the Tangail (river flood) and the Khatunganj areas (tidal flood[87]). The table reveals that an average sample of industries in the main case study area has a capital intensity of only less than 23,000 Taka, while in the Khatunganj area this is estimated as 21,000 Taka[88]. Hence, the industries in both the areas are of tremendously low capital intensities, by any Bangladesh standards, let alone international ones. It appears that capital intensities have no close association with industry type (X^2 values are not significant). The most striking feature is that in both of the study areas, the proportion of machinery damage (to value) shows no significant difference among various types of industries (X^2 values not significant)

Table 5.24 presents a comparative analysis of flood losses in relation to different levels of capital intensity. It was postulated that more capital-intensive industries would have larger proportion of damages to machinery/equipment. It is revealed that as expected, higher capital-intensive industries have higher potential absolute damages to machinery.

However, it is revealed that the percentage damage to value of machinery declines with the increase in capital intensity, which is contrary to the hypothesis postulated. This holds good for the two study areas, and all areas combined. In all the cases, X^2 and r values are highly significant, with negative signs associated with all of the r values. It is difficult to explain this finding. However, several points can be raised in this context. First, relatively lower capital-intensive industries are presumably smaller-sized industries, and higher capital-intensive units are relatively larger-sized units. The converse might also be true. Hence, smaller-sized units are likely to have a larger proportion of potential damage to

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[86] The capital here includes only machinery and equipment. Capital-intensity (denoted by I) is defined as $I = K/L$, where K=value of machinery/equipment and L=Labour input.

[87] The inclusion of the third area in the analysis is due to the fact that the area includes relatively larger number of medium and large industries. The second area (flash flood) is excluded because it contains mostly small and cottage type industries.

[88] This compares extremely unfavourably in that the capital intensity (in terms of machinery/equipment) in an average private leather plant, for example, estimates as 0.2 million Taka at 1988 price (Huq and Islam 1990), while the capital intensity (in terms of all fixed assets) for a large-scale nationalised fertilizer plant amounts to approximately 10 Million Taka (Huq and Islam 1992).

Table 5.23: Analysis of capital intensities by type of industries

Tangail : Major river flood

Type of industries	Average capital intensities (00 TK)	Average potential damage	Per cent damage to machinery/equipment
Food & agro-based	154	19731	24.3
Cotton & textiles	466	28230	24.3
Timber & furniture	65	13940	29.8
Engineering	141	12712	27.3
Miscell & service	225	8584	18.1
ALL INDUSTRIES	226	15742	23.6
Chi squared value	7.8 (P<.45)	6.6 (P<.58)	6.5 (P<.59)

Khatunganj : Tidal flood

Food & agro-based	279	19333	9.1
Cotton & textiles	353	7947	1.2
Timber & furniture	88	1569	12.4
Engineering	196	1229	7.3
Miscell & service	135	6350	7.9
ALL INDUSTRIES	212	8902	8.0
Chi squared value	7.5 (P<.49)	15.2 (P<.00)	7.0 (P<.14)

Note : Capital intensity in this analysis denotes intensity in terms of machinery/equipment, and is defined as Intensity = Value of machinery/Employment; One extreme case in the main study area is excluded to avoid distortion.

Table 5.24: Analysis of flood losses by capital intensity of industries

Industries by capital intensity	Potential damage to Machinery /Equipment (TK)	X^2 & r value	Per cent damage to Value of Machinery /Equipment	X^2 & r value
Main study area Capital intensity (00 TK)				
Low (< 36)	3671	X^2=23.2 (P<.02) r=.29 (P<.03)	26.2	X^2=10.2 (P<.04) r=-.36 (P<.01)
Medium (36 - 180)	12118		29.4	
High (> 180)	37151		11.8	
ALL TYPES	15742		23.6	
Area 3 Capital intensity (00 TK)				
Low (< 36)	9777	X^2=3.5 (P<.48) r=.15 (P<.44)	32.2	X^2=23.4 (P<.00) r=-.49 (P<.01)
Medium (36 - 180)	5359		6.6	
High (> 180)	13817		3.4	
ALL TYPES	8902		8.0	
All three areas Capital intensity (00 TK)				
Small (< 36)	3890	X^2=27.6 (P<.00) r=.23 (P<.02)	24.9	23.9 (P<.00) r=-.31 (P<.00)
Medium (36 - 180)	7943		18.6	
High (> 180)	26334		10.5	
ALL TYPES	13388		17.2	

Note : Capital intensity in this analysis denotes intensity in terms of machinery/equipment, and is defined as

Intensity = Value of machinery/Employment;

X^2 = Chi squared value, and r = Pearson's correlation coefficient. Significance of r represent two-tailed significance; one extreme case in the main case study area is excluded in order to avoid distortion.

machinery/equipment - the units which, as evidenced earlier, are more vulnerable to floods in terms of both direct and indirect damages. Secondly, it is likely that the lower cost machinery/equipment used by smaller units are relatively bulky, and placed in more exposed positions compared with those of the costly machinery/equipment which might have received greater attention for protection. Thirdly, as discussed earlier, most of the industries under investigation are smaller-sized (at best, some medium-sized) units, by any standard, for which within-group capital-intensities have not varied considerably. This is also evident from Table 5.23.

The analysis leads to a conclusion that relatively lower capital-intensive industries are subject to higher flood losses in proportional terms, which, in effect, reenforces the earlier finding that relatively smaller-sized industries are more vulnerable to floods in Bangladesh.

5.2.7 'Ripple' Effects of Indirect Loss over Town, Region and Nation

To gauge the effects of flooding owing to linkages in the economy and the system as a whole, a few pertinent questions were included in the interview schedule. One such question was: What proportion of your production/business lost in the flood do you think is taken up by each of the following competitors? Competitors within your town? Competitors within region? Other competitors in country? Foreign firms? And so on. In this way, the ultimate permanent loss to the country due to production losses to flooded firms are assessed. The basis of assessing the linkages in the economy emerges from the assumption that, by and large, firms are well informed about both sectoral and regional destinations of output including its end-use. They are also knowledgeable about sectoral and regional origins of their purchases. In other words, presumably, the enterprises are generally aware of the demand and supply conditions prevailing in different parts of regions and the country[89].

Table 5.25 presents the percentage of output loss in the main case study area and its estimated distribution over town, region and the country, as a whole. As regards the percentage of output loss (to monthly output) both the industries and business sectors suffer output/turnover losses approximately equal to 1.6 times their monthly output. The extent of loss is the highest in the case of engineering units (209%) while this is the lowest in the case of food

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[89] During the exploratory trip to study areas and pre-testing of questionnaires, the above assumption was proved largely valid.

Table 5.25: Estimated distribution of output loss over Town, Region and Nation

Industries : Major river flood: Tangail

Type of industries/ business	Per enterprise output/turnover loss (TK)	loss as % of monthly output/ turnover	Value Added as % of output/ turnover	% of output loss at levels		
				Town	Region	Nation
Food & agro-based	719243	142	26	76	55	45
Cotton & textiles	256171	147	50	90	83	66
Timber & furniture	76618	178	40	71	50	49
Engineering	66678	209	64	82	70	54
Miscell & service	76421	156	50	91	82	60
ALL TYPES	230259	165	48	80	64	52
(X^2 sig level)	(.10)	(.45)	(.25)	(.38)	(.02)	(.32)

Business : Major river flood : Tangail

Food & grocery	133589	111	17	84	78	76
Cloth & footwear	180050	183	13	90	81	56
Drugs & chemicals	586427	108	9	82	76	34
Electrical	739552	193	12	97	97	74
Motor /cycle parts	238013	126	10	69	57	36
Construction	968627	238	11	79	58	42
Miscellaneous	107357	213	28	95	92	73
ALL TYPES	324328	163	16	84	75	52
(X^2 sig level)	(.05)	(.33)	(.38)	(.15)	(.19)	(.00)

Note : % of output loss denotes weighted average;
: Output loss is net of recovery, transfer etc;
: Region is defined as greater district where the town is located;

and agro-based industries (142%). Across the business units, the variations of percentage losses are relatively higher, ranging from 108% (in drugs and chemicals) to 238% (in construction materials)[90].

The impacts of flooding faded considerably with geographic and economic distances from the flood events. Thus the 'ripple' effects of flooded enterprises decline gradually from town, region and the nation, as whole. The national losses are the ultimate and permanent losses, estimated net of all recoveries taken place at town, region and country levels. In the industries sector, the total net losses (net of recovery) are distributed by 80%, 64% and 52% over town, region and country respectively. In other words, the firms within the town recover their production losses by 20%, while those in the region (the greater district) compensate by 36%. The country, as whole, can ultimately make up about 48% of the total production loss suffered by the sample firms. The national loss is estimated to be the lowest (45%) in the case of food and agro-based units, and the highest (66%) in the case of cotton and textiles. There is no evidence, however, that output loss in the town and country differs among industries type (X^2 values are not significant), while there is evidence that regional losses are significantly different among industries types (X^2 value is significant). In the business sector, the distribution of output loss is close to that of industries: 84%, 75% and 52% in town, region and country respectively. Thus, the business firms within the town recover their turnover losses only by 16%, while the region makes up by 25%. The nation, as whole, can take up about 48% of the total turnover loss. In business sector, evidently, turnover losses in the town and region do not differ among business types (X^2 values not significant), while there is evidence that national losses are significantly different among types of business outlets (X^2 value significant).

5.2.8 Differential 'Ripple' Effects by Various Floods

A similar analysis is carried out to assess whether there are differential 'ripple' effects caused by different floods. Table 5.26 shows the estimated regional and national losses experienced by sample industries and business units in three different floods. It is apparent that for industries, the net output loss suffered by region and nation in the case of the flash flood are much lower than that suffered by the major river flood. Likewise, in the case of the tidal

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[90] X^2 values, however, demonstrate that the variations in both industries and business are statistically insignificant.

Table 5.26: Estimated Regional and National loss to output caused by different floods

Industries :

Flood type	Per enterprise output loss (000TK)	loss as % of monthly output	% of output loss to	
			Region	Nation
Major river flood:1988	230	165	64	52
Flash flood:1993	88	82	50	40
Tidal flood:1991	798	201	41	32

Business :

Flood type	Per enterprise turnover loss (000TK)	loss as % of monthly turnover	% of turnover loss to	
			Region	Nation
Major river flood :1988	324	163	75	52
Flash flood:1993	126	127	58	31
Tidal flood:1991	902	181	40	31

Note : % of output/turnover loss denotes weighted average;
: Methodology of estimating National loss is explained in Section 5.2.7.

flood, the output losses in industries suffered by region and nation are much lower than those suffered in the river flood. Also, the net turnover losses in the business sector suffered by region or nation are lower than that suffered in the major river flood. This is perhaps not difficult to explain. In the case of the major river flood, most of the country (62% of the area) is flooded, when the scope of the recovery at the national level is likely to become more limited. On the other hand, in the case of isolated and localised floods, such as flash or tidal floods, the scope for recovery is likely to be higher. In other words, it is most likely that much of losses suffered by the flooded enterprises are compensated by other firms; presumably non-flooded units from outside the location throughout the region and country. Hence, regional economies in Bangladesh are considerably resilient in terms of recoveries.

In aggregate, the ultimate economic losses to nation in both the sectors, industries and business, are estimated as slightly more than half of the total output losses suffered by the sample firms in the river flood area. The national losses caused by flash and tidal flood are estimated to be in the range of 31 to 40 per cent in these sectors. The analysis seemingly contradicts what is inferred in Chapter 8 on Macro-level Impacts of Flooding, where it is concluded that ultimately ripple or the spill-over effects of flooding on industries sector at the national level tend to be trivial.

Several points may explain this contradiction. The above analysis concerns firms in three areas: a secondary town, a Thana town (comprising semi-urban areas with some rural characteristics) and a city location. Incidentally, most of the sample industries and businesses are small or, at best, medium-sized units. Even some are operated in the cottage line of activities. The above micro-level analysis is carried out on gross output. The macro-level analysis, on the other hand, is carried out on output of selected large industries and value added of the industry sector, as a whole. There are potentially other measures of recovery and restorations, such as the those initiated by government, NGOs and international agencies. Nonetheless, the above analysis needs to be used with caution because of among other things, the small size of sample and its skewed distribution.

5.2.9 Summary

In the preceding sections of the chapter, the empirical analysis for both industries and business units generally manifests enormous variations in damage figures by type of enterprises and by type of floods. For example, the standard deviations for damages demonstrate a wide range of variations, estimating as much as nearly double the mean damage values. The extent of damages due to different types of floods is significantly different. In terms of both absolute and proportional (to value) damages, the more devastating floods are the flash and tidal flood types, which destroy about 46% and 41% of total assets in industries respectively. Despite the fact that the major river flood has a much longer duration, the damage accounts for 17% of the total value of assets. In business, the proportional damages are estimated as 31%, 26% and 53% in the river, flash and tidal flood respectively.

In respect of damage components, among the direct damages in industries, stock is by far the most severe damage component in the total damages, for all the flood types, accounting for 24%, 17% and 65% to total damage in the three floods respectively. In business units, stock damage comprises 57%, 53% and 33% of the total damage in the three floods respectively. Indirect damages generally constitute the major part in the total damages, accounting for 57%, 47% and 26% in industries, and 39%, 40% and 41% in business units, in the river, flash and tidal flood respectively.

The analysis of association and correlations indicates that absolute damages are generally positively related to values of the properties in the case of both industries and business for all the study areas. Nevertheless, the proportional damages (to value), for structures, machinery and stock, are generally found to be inversely related to their values. Generally, the proportional damages, rather than absolute damages, are found to be directly related to depths or durations. By and large floor space is positively related to both actual and potential damages in the commercial sectors. Total employment is positively and directly related to value of properties moved, and damages avoided by removal.

The study reveals that the small-sized enterprises (particularly the industrial units) generally are more vulnerable to flood hazard. This finding well corroborates the finding achieved for residential properties - that the poorer community is the more vulnerable to floods.

The study also reveals that the impacts of flooding are considerably decayed with distance, geographically and economically from the flood events. Thus the 'ripple' effects of flooded enterprises for both industries and business decline gradually from town, region and the country, as whole. The net output loss suffered by region and nation in the case of the flash or tidal flood are much lower than that suffered by major river flood. This is understandable in that in the case of the widespread river flood the scope of recovery at the national level is likely to become more limited. In the case of isolated and localised floods, such as a flash or tidal flood, on the other hand, the scope for recovery is likely to be higher.

CHAPTER 6: FLOOD LOSS POTENTIALS AND ASSESSMENT METHODS - OFFICE, PUBLIC BUILDINGS AND ROADS

6.1 Flood Loss Potentials in Office and Public Buildings

6.1.1 Introduction

This Chapter seeks to assess flood loss potential in offices, public buildings and roads. The Chapter is organised in two main sections. The first deals with flood loss assessments in office and public buildings and the second section deals with flood loss assessments in the roads sector.

The offices include government offices, banks and private offices, while public buildings include mainly those dealing with public utility networks such as electricity, gas, water, and health and educational services (e.g. clinics, hospitals and schools). The religious institutions like mosques and temples, which are also considerable in the study area are included. The offices and public enterprises have some common characteristics in that they provide services to the members of the public, which are not usually priced in the market, rather than produce any physical goods. Since there are likely to be overlaps in the definition of the two sub-sectors, the research includes offices and public buildings together in dealing with flood loss assessments. The study covers 5 broad categories of office and public buildings: (1) government office (2) utility (3) government and private hospitals (4) educational and religious institutions and (5) non-governmental organisations and other private offices.

Flood losses to office and utility networks arise in a number of ways: direct damage to physical facilities may cause service disruptions to consumers, individual public and business enterprises, in consequence of which both service providers and the consumers may suffer disruption to their respective business. This may again occur within and beyond the flooded economy. In effect, depending on the linkages in the system, the financial indirect loss incurred by the utility network and its consumers may cause chain of effects on the rest of the economy in phases, and in innumerable dimensions and directions[91]. Additionally, given that some of the public services 'typically involve externalities' (Parker et al 1987), it is difficult to quantify output of services (e.g. benefits of education). Although the assessment

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[91] Such effects due to linkages are covered in Chapters 5 and 8 in some detail.

of indirect losses at the firm or individual level, caused due to disruptions to office or utility industries, generally remains problematic, it is feasible to quantify some of such losses through conducting a separate site specific survey. Following that the indirect impacts in the form of linkage effects are covered in the preceding chapter (on industries and business), it can be argued that the some of the indirect impacts in the office and public service sector have already been incorporated, at least to some extent at the national level. Hence, further assessments of indirect impacts in this sector is likely to cause double-counting with those assessed in the commercial sectors. The research therefore seeks to deal with only the direct flood damage potential in the office and public sector.

6.1.2 Modelling Flood Losses

The problems of flood loss modelling associated with residential and commercial sectors are generally relevant to this sector. As is the case with other sectors, the major problem of generating flood loss potential data relates to the failure in establishing stage-damage functions following wide diversities in the type of office and public enterprises[92].
As is adopted in other sectors, thus, the study uses the 'regression' approach to generate a fairly consistent data set at disaggregated levels of depths and durations.

A number of single equation loss models are explored. The models for each damage component are tested for both linear and double logarithm forms. For reasons explained earlier the linear models do not yield a good fit. Additionally, such models do not provide consistent information in that these give negative damage in shallow flooding in some cases[93]. Thus the double logarithmic models are deemed more appropriate for modelling losses in this sector. As explained in other chapters, the main consideration for the use of double logarithmic models is that these provide zero damage at zero depth or duration.

Tables A6.1 and A6.2 present results of the flood loss models. Because of the small sample size the models are not estimated for individual groups of properties, but these are lumped together, using property groups as dummy variables. For reasons explained earlier the

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[92] The land use survey suggests that there are as many as 50 broad type of office and public units.

[93] Much of this is contributed to a large negative intercept.

Duration variable is used as a dummy variable[94]. The two damage components are considered while modelling damages: structural and equipment. Equipment mainly consists of equipment, machinery and furniture. Other stock, if any, is added with this component. The damage to educational institutions mainly includes damage to structure and furniture with a few equipment items in some cases, while damages to religious institutions (e.g. mosques, temple) include only those to structures as such units have few inventories.

As can be seen from the table, R^2 values are highly significant (at more than 99% level) implying high predictable power of the models. The regression coefficients are also generally found to be significant at an acceptable level of significance. The only exception is for the dummy variable, Duration, in case of per unit and per square metre damages to equipment. In none of the case is the variable Duration found to be significant. Additionally, an expected negative sign is not found in the case of the equation with the per unit equipment damage. In the case of the equation for the per square metre equipment damage, however, the sign is negative. Thus, there is no alternative but to generate estimates of per unit potential damages from the per square metre data by using average floor spaces. The insignificant difference in the per square metre equipment damages between the two durations implies that in most cases the duration up to the 7 days is the critical magnitude for such damages.

6.1.3 Construction of Damage Data Sets

Average group damage data sets are constructed for per unit of establishment and per square metre of floor spaces. The data sets are constructed for the two damage components: structure and equipment. The sub-sectors and all groups together are individually tested. However, the model for ‘all groups’ is used in generating the damage data mainly because of the stable relationship (through incorporating variations due to ‘groups’) provided by a relatively larger sample size.

The "per establishment" average damage data sets are presented in Tables 6.1 and 6.2, and the "per square metre" data sets are presented in Tables 6.3 and 6.4.

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[94] Dummy for Duration = 1 for up to 7 days and Duration = 0 for greater than 7 days.

Table 6.1: Per unit estimated potential damage to office building at various depths: (Tangail study area)

Duration = up to 7 days Value in 1992-93 Taka : £ = 65 Taka(app)

Office category /Damage component	flood depth above floor(metres)				
	.30	.61	.91	1.22	1.52
Government office					
: Structure	3964	5288	6221	7008	7662
: Equipment etc	11014	14144	16285	18058	19511
: TOTAL	14978	19432	22506	25066	27173
Utility office					
: Structure	184653	246352	289815	326471	356961
: Equipment etc	41342	53090	61127	67781	73239
: TOTAL	225995	299442	350942	394252	430200
Hospital & Clinics					
: Structure	21001	28019	32962	37131	40599
: Equipment etc	475676	610842	703311	779867	842675
: TOTAL	496677	638861	736273	816998	883274
Educational & Religious institutes					
: Structure	14063	18762	22073	24864	27187
: Equipment etc	29814	38285	44081	48879	52816
: TOTAL	43877	57047	66154	73743	80003
NGOs & other private office					
: Structure	280	373	439	495	541
: Equipment etc	1994	2560	2948	3269	3532
: TOTAL	2274	2933	3387	3764	4073
Sector average					
: Structure	44792	59759	70302	79194	86590
: Equipment etc	111968	143784	165550	183571	198355
: TOTAL	156760	203543	235852	262765	284945

Table 6.2: Per unit estimated potential damage to office building at various depths: (Tangail study area)

Duration > 7 days Value in 1992-93 Taka : £ = 65 Taka(app)

Office category /Damage component	flood depth above floor(meters)				
	.30	.61	.91	1.22	1.52
Government office					
: Structure	4237	5653	6650	7491	8191
: Equipment etc	11042	14180	16326	18103	19561
: TOTAL	15279	19833	22976	25594	27752
Utility office					
: Structure	197390	263345	309805	348990	381582
: Equipment etc	41446	53223	61280	67950	73423
: TOTAL	238836	316688	371085	416940	455005
Hospital & Clinics					
: Structure	22450	29951	35236	39692	43399
: Equipment etc	476867	612371	705071	781819	844784
: TOTAL	499317	642322	740307	821511	888183
Educational & Religious institutes					
: Structure	15033	20057	23595	26579	29062
: Equipment etc	29888	38381	44191	49002	52948
: TOTAL	44921	58438	67786	75581	82010
NGOs & other private office					
: Structure	299	399	469	529	578
: Equipment etc	1999	2567	2955	3277	3541
: TOTAL	2298	2966	3424	3806	4119
Sector average					
: Structure	47882	63881	75151	84656	92562
: Equipment etc	112248	144144	165965	184030	198851
: TOTAL	160130	208025	241116	268686	291413

Table 6.3: Per square metre estimated potential damage to office building at various depths (Tangail study area)

Duration up to 7 days

Value in 1992-93 Taka : £ = 65 Taka(App)

Office category /Damage component	flood depth above floor(meters)				
	.30	.61	.91	1.22	1.52
Government office					
: Structure	26	34	40	45	49
: Equipment etc	71	91	105	117	126
: TOTAL	97	125	145	162	175
Utility office					
: Structure	509	679	798	899	983
: Equipment etc	114	146	168	187	202
: TOTAL	623	825	966	1086	1185
Hospital & Clinics					
: Structure	29	39	46	52	56
: Equipment etc	660	847	975	1082	1169
: TOTAL	689	886	1021	1134	1225
Educational & Religious institutes					
: Structure	54	72	85	96	105
: Equipment etc	115	147	170	188	203
: TOTAL	169	219	255	284	308
NGOs & other private office					
: Structure	2	3	4	4	5
: Equipment etc	17	22	25	28	30
: TOTAL	19	25	29	32	35
Sector average					
: Structure	124	165	195	219	240
: Equipment etc	195	251	289	320	346
: TOTAL	319	416	484	539	586

Table 6.4 Per square metre estimated potential damage to office building at various depths (Tangail study area)

Duration > 7 days

Value in 1992-93 Taka : £ = 65 Taka(App)

Office category /Damage component	flood depth above floor(meters)				
	.30	.61	.91	1.22	1.52
Government office					
: Structure	27	37	43	48	53
: Equipment etc	71	91	105	117	126
: TOTAL	98	128	148	165	179
Utility office					
: Structure	544	726	854	961	1051
: Equipment etc	114	147	169	187	202
: TOTAL	658	873	1023	1148	1253
Hospital & Clinics					
: Structure	31	42	49	55	60
: Equipment etc	661	849	978	1084	1172
: TOTAL	692	891	1027	1139	1232
Educational & Religious institutes					
: Structure	58	77	91	102	112
: Equipment etc	115	148	170	188	204
: TOTAL	173	225	261	290	316
NGOs & other private office					
: Structure	3	3	4	5	5
: Equipment etc	17	22	25	28	30
: TOTAL	20	25	29	33	35
Sector average					
: Structure	133	177	208	234	256
: Equipment etc	196	251	289	321	347
: TOTAL	329	428	497	555	603

The use of per establishment damages is likely to be erroneous in that variations in floor spaces are enormous and the distribution is skewed so that the ordinary least square method of estimation is likely to be associated with some bias. Hence, the use of "per square metre damages", rather than "damages per unit of establishment ", is more logical, except for any desk level appraisals. This is particularly because of the presence of a few extreme values.

Per square metre structural damages show large variations among some groups. The maximum variation occurs in the Utility office group. Some of such large structural damages are due to the use of replacement costs in the damage assessments (e.g. in case of demolishing structures in case of protection from dampness). However, it is suspected that a few extremely large variations are caused due to the potential misreporting of some of the equipment damages having been merged with the structural component. Following this, perhaps, the use of per square metre 'total' damage, rather than the individual component damage is more appropriate.

A comparison of the damageability in office buildings with those in other sectors show that per square metre potential damages in this sector are higher than those in the residential sector, but lower than those in the industries and business sectors. For example, the per square metre total damage to office and public enterprise (e.g. at 0.61 metre depth and 7 days duration) is estimated as TK 416, compared with the per square metre total damage of TK 1217, TK 4323 and TK 213 in the industry, business and residential sector respectively.

6.2 Flood Loss Potentials - Roads Sector

6.2.1 Potential Flood Impacts on Roads Network

Floods may cause physical damage to roads and other transport networks, such as railways, sea-ports or airports. At the same time, floods may cause traffic and communication disruptions. The physical damage is termed the direct damage, and the damage due to traffic disruptions is termed the indirect damage. Depending on the traffic network with the provision of alternative routes in individual locations, commuters may suffer different types of indirect losses. Two major types of such losses can be identified. The first type includes the additional (marginal) transport costs incurred in the undertaking of an alternative route or journey. The second type includes the opportunity cost caused by deferment or delay of a journey. If a flood cuts a road, for example, which has no alternative route, commuters dependent on it will, unless they can 'defer', have to suffer maximum losses because of lack of 'redundancies'.

Potential Indirect Impacts of Flooding

In Bangladesh, dependencies on roads during floods are likely to be largely offset by 'natural' redundancies created by wide-spread waterways through a large number of water transports. A large part of the country's area remains submerged in the flood water nearly half of the year, and as such country boats play an important role in the total transport system. There are at present several hundred thousand non-mechanised country boats with varying shapes and capacity, ranging from 1 tonne to 3 tonnes (Hossain 1991). About 80% of Bangladesh's 68,000 villages are still dependent on this traditional transport (Jansen et al 1989). The country boats, mostly operated commercially, have a combined carrying capacity of around one million tonnes, three times greater than all vessels in the public and private inland water transport sub-sector combined. Additionally, they account for nearly 60% of all employment in the whole transport sector (Jansen et al 1989).

Especially during large and wide-spread floods, the boats become the single most important mode of transport. The number of boats plying during floods invariably figures to many-fold. Most of the boats are still manually driven. However, with some attempts of modernisation of the country boats in the recent past, a considerable number of boats are now engine driven. Particularly the country boats are slow but generally viewed as relatively cheaper modes of transport. It is a matter of investigation whether the overall costs (by imputing cost of time) of transport by boats are still on the lower side. Following is a brief empirical analysis to investigate the efficiency of the water transport over roads transport in terms of time and cost.

Comparative Advantages and Disadvantages of Water and Roads Transport

So far as the sample commercial enterprises are concerned, very few units use water as their usual mode of transport at present (Table A6.3 presented in Appendix Section). Averaged over all the three urban areas, only 3 to 4 per cent of the industrial units, and up to 2 per cent of business units, use water-ways in transporting their merchandise in the usual time of the year. Incidentally, the existing river transport system in all the three urban study areas is poor and there are few water transports available for commercial purpose, which could be one of the reasons responsible for such a low incidence of the use of water transports.

Information was sought during the survey to examine whether the commercial units can run their business through waterways during floods, and if so, what are the comparative advantages and disadvantages of the two modes of transport. The results presented in Table A6.4 (Appendix Section) reveal that generally the enterprises find it disadvantageous, in terms of time, and advantageous, in terms money, to use water rather than road transport. For example, averaged over all the three areas, about 91% of the industrial units and 87% of the business units find water transport disadvantageous in terms of time. However, about 47% of the industrial units and 59% of the business units find water transport cheaper over roads transport. In terms of money, the industrial enterprises estimate the water transport as cheaper by 32%, while it is time-consuming by about 189% over roads transport. The business units, however, regard water transport cheaper by 86%, while it is time-consuming by 179% over roads transport. These estimates hold good given the existing water transport network and facilities in the study locations, which are currently meagre and informally organised especially from a commercial point of view. If any improvements to the inland water transport network are undertaken, it is expected that the water sector will be in a further comparative advantage. While it is generally recognised that indirect impacts might be as important, as Bangladesh is being traversed by more than 700 rivers and tributaries (total length being 22,000 kilometres) covering a navigable water network of more than 8,000 kilometres, natural 'redundancies' at times of floods are enormous compared with roads. Hence, it is believed that indirect impacts of flooding of roads will largely be offset by water transports[95].

Potential Direct Impacts of Flooding on Roads

The direct physical damage caused to road infrastructure by floods can be colossal in Bangladesh. Because of the requirement of bridges and culverts to cross many canals and rivers, and poor engineering characteristics of the soil, the cost of construction of roads is one of the highest in the world (Jansen et al 1989). Conditions also demand that greater than normal attention be devoted to maintenance. In the 1987 flood, for example, more than 15000 kilometres of roads and highways were damaged/destroyed, and about 1200 bridges

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[95] 'Natural' redundancies are also expected to create considerable income and employment impact in the face of a stimulus to the boat making industry during floods.

and culverts were washed away[96]. The damage extent in the 1988 flood was even far worse. Unfortunately, the assessment of direct damage potential to roads has received little attention in the contemporary flood research[97]. The present research thus seeks the assessment of only direct damage caused to roads infrastructure.

6.2.2 Problems of Assessing Direct Damage to Roads

The assessment of flood loss potential in roads sector has always been a problem. Roads are always subject to wear and tear due to host of factors such as traffic loads, construction type and quality, and other external events. Almost every year roads demand attention. Additionally, some modifications or enlargements to existing structures are often carried out. All these contribute to the failure to precisely separate repair works exclusively attributable to floods.

Thus the construction of depth-damage data sets for the roads transport sector poses special problems. It is difficult to construct standard or average depth-damage data as the physical damage are often unrelated to depths. Moreover, flood losses in this sector are more likely to be a function of durations, rather than depths. The situation is made more complex by the presence of several other factors. First, not all roads are expected to be equally vulnerable to flood water. Different roads are flooded at different depths for different durations, while the road-specific repair costs are not usually available. Such costs are often available for the total number of roads combined. The physical damages largely depend on the type of construction e.g. rod-concrete-cement (RCC), concrete-cement (CC), herring-bone (HB) or *kutcha* (made of earth) (Table A6.5). For example, a RCC road is not normally damaged even with a deep and long duration flooding, while a CC road may be subject to considerable damage even with a shallow depth and moderate duration of flooding. A HB or *kutcha* road, on the other hand, may substantially be damaged with the increase in durations.

Second, the physical damages largely depend on the pre-flood conditions and subsequent traffic loads during the time of flooding. Some roads are not likely to be considerably damaged in shallow flooding (e.g. 0.15 metre), but they are significantly damaged if motor

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[96] According to The Fourth Five Year Plan, October, 1990.

[97] For indirect impacts, however, detailed methods of assessment are available in Parker et al (1987).

or robust traffic is in operation during flooding, as is often the case in Bangladesh. These roads, on the other hand, are not substantially damaged even with a deep flooding as no such robust vehicles can ply in that situation. In such conditions, shallow flooding can create more damages to some roads than those being deeply flooded. Hence, in all these complex situations consistent standard or average damage data sets (depth-damage or duration-damage data) are almost inconceivable. However, only some guidelines can be set towards assessing potential damages in some actual flood events, from which a potential data set can be constructed.

6.2.3 Principles of Evaluation of Direct Damage to Roads

6.2.3.1 The Analytical Framework

The methodology of evaluation of physical damage to road networks to some extent resembles to that adopted in the analysis of flood impacts at macro-level (Chapter 8). The assessment of physical damage caused by floods involves using time series data on repair costs. The framework involves estimating the trend of growth on repair costs over a reasonably long period. So the growth curve estimated through the Least Squares method in relation to time is expected to manifest the direction net of all changes. A semi-log trend equation (implying constant rate of change) is considered more appropriate for the analysis. The semi-log model is of the form, $Y = A' e^{BX}$ Or, $\text{Log } Y = A + BX$ which is linear in log Y and X, X being the independent (Time) variable and Y, the dependent variable (repair cost).

Now, even if the model were an extremely good fit, it is obvious that all the points of the observations will not lie exactly on the trend line. Thus, it is necessary to introduce a stochastic factor, usually called disturbance factor (or residuals), into this relationship. Thus, $Y = A'e^{BX} U'$ Or, $\text{Log } Y = A + BX + U$. The estimated residuals or the deviations from the trend form the basis of the assessment of physical damages to roads caused by flooding.

The major assumption of the analysis is that the year-on-year impacts reflected by the individual residuals is attributable exclusively to corresponding floods in corresponding years, given other exogenous variables, if any, remaining constant. The other assumption is that the budget amounts or actual repair costs are not influenced by any other factors e.g. fund allocations or any political motivations. If, however, these are influenced for any reason, it is assumed that the budget amounts or actual expenses are proportional to repair needs, so that trends estimated are not significantly distorted. In real circumstances repair costs are likely to be less than repair needs, so that in such a case the above method of evaluation may suffer from some underestimation.

6.2.3.2 Repair-cost Data and Methods of Assessment

The analysis is carried out on *pucca* type of roads maintained by two organisations, namely the Roads and Highways (R & H) Division and the Pourasava (Municipality) authority[98]. The information on repair costs are available for a 10 year period, 1983/84 through 1992/93, the source being mainly the engineering department of the two organisations. In the case of R & H roads, the data refer to budget amounts for repairs, rather than the actual repair cost, over the period which are available for the total lengths of roads (that are controlled by the Division)[99]. The Pourasava part is segregated from the total lengths of roads. In the case of the Pourasava roads, however, information on yearly actual repair costs are available. The repair costs, budgeted or actual, include costs of repairing culverts and bridges damaged, if any.

Per kilometre repair costs are then estimated on the assumption of annual growth rate of 10% in case of the Pourasava roads. For the R & H roads, the total length of roads are said to be constant during the period of 10 years under investigation. The per kilometre costs are then converted to constant (1992/93) prices[100]. The roads under the Pourasava are maintained on a almost year-on-year basis, but in the case of the R & H roads, major repairs are reported to be undertaken only every few years, unless severe damage is caused by any abnormal events such as floods. However, the annual repair costs do not usually reflect damages occurring in the corresponding year. The annual repairs that are carried out are attributable to the damages in the past one or two years. This is because of the time required in the process of allocation of funds and also the discrepancies in the financial (July-June) and the flood year (calendar year). From the historical repair cost data, thus, 2-year moving

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[98] The information on repair costs of the herring-bone or *kutcha* type are not available.

[99] According to relevant source, budgeted costs are approximately 20% inflated over what are needed for repairs.

[100] The deflator for building materials is used for the purpose.

averages are worked out in order to eliminate potential short-term fluctuations[101]. The semi-logarithmic trends are then estimated, from which the deviations (or residuals) are estimated.

6.2.3.3 Results and Construction of Potential Damage Data

Two trend equations are estimated separately for the R & H roads and the Pourasava roads. The equations are estimated as follows:

R & H roads

$$D_r = \underset{(.2225)}{1.0490} - \underset{(.0341)}{.079882}\ Y$$

$R^2 = .4401$, Adj $R^2 = .3601$, $F = 5.5$ ($P < .05$ $N = 9$)

Pourasava roads

$$D_r = \underset{(.6020)}{1.3717} - \underset{(.0922)}{.2184}\ Y$$

$R^2 = .4246$, Adj $R^2 = .3424$, $F = 5.2$ ($P < .06$ $N = 9$)

where, D_r = Per km average (moving average) repair costs (00,000 TK), Y = year, Adj R^2 = coefficient of determination (adjusted for degrees of freedom), F=F-statistic, P=F significance level and N=sample size (for moving average); figures in parentheses represent standard errors.

In the case of the R & H roads, both total budgets and per Km budgets are on the decline. In the case of the Pourasava roads, although annual repair budgets are usually increased on year-on-year basis, the estimated trends indicate that per kilometre actual costs of repair are on the decline, indicated by a negative growth rate. The negative growth rates (presumably because of resource constraint) are 8% and 22% for the R & H and the Pourasava roads respectively.

In all, the total length of roads in Tangail town is 110 km, of which about 61 Km are *pucca* and 49 Km are of *kutcha* or the herring-bone type. The R & H roads are all of *pucca* type, while the Pourasava roads are of three types: *pucca*, herring-bone and *kutcha* (Table A6.5).

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[101] If the data were available stretched over a longer period, ideally, a 3-year moving average method could perhaps be more appropriate.

The roads maintained by the R & H are wide, elevated and of a high construction quality, while those maintained by Pourasava are generally relatively narrow, less elevated and of a sub-standard construction quality. As regards potential traffic loads during floods, the R & H roads usually experience minimum loads as compared to the crowded Pourasava roads (Table A6.6).

The estimated trends on repair costs, and deviation of actual per Km costs from the trends are shown in Tables 6.5 and 6.6 for the R & H roads and the Pourasava roads respectively. As can be seen from the Table 6.5, in the case of the R & H roads, the deviations of actual repair cost from the trends in the year 1987 and 1988 flood (a return period of approximately 10 and 40 years respectively) are TK 42,000 and 106,000 respectively. It can be recalled that the trends estimated in the case of the R & H roads are on the budgeted costs, which are estimated to be 20% inflated over the actual repair costs. Thus the per kilometre flood damage in the R & H roads estimates at TK 33,600 and TK 84,800 in the two floods respectively. In the case of the Pourasava roads, however, the deviations shown are from the actual repair costs, which are estimated to be TK 92,000 and TK 242,000 respectively (Table 6.6).

Given that the time series data on the repair costs include a short period, and this does not include flood years with a 2, 5 and 20 year return period, the damages caused by these floods are estimated through linear regression. The coefficients of determination of the deviations (from trend) with corresponding flood levels over the 9 year period are estimated as $r^2=.26$ and $r^2=.16$ for the R & H and the Pourasava roads respectively. The coefficients are found to be significant at .16 and .26 level respectively.

The estimated per kilometre cost of construction for different types of roads and the extent of inundation of roads by floods of various magnitudes are presented in Table 6.7. As can be seen from the Table an average R & H road cost about TK 4.2 M per kilometre, which is about 2.5 times that of TK 1.7 M, the per kilometre cost of a Pourasava road. As regards the extent of inundation to *pucca* roads, 100% of the roads are flooded in a 20 and 40 year flood, whereas about 98% and 89% of the roads are flooded in a 10 and 5 year flood respectively (See Land Level Survey in Chapter 7). A 2 year flood inundates 27% of the roads. The extent of inundation by the R & H and the Pourasava roads are also shown separately in the table. Using data on the extent of flooding from the Table 6.7, the potential direct damages to *pucca* roads in 5 different floods are estimated. The results are presented in Table 6.8. The proportion of damages (to value) for the two types of roads are also shown. As is evident, the total damage to *pucca* roads in Tangail town estimates at TK 3.5 M and TK 11.5 M in the two major floods, the 1987 and 1988 flood (with a return period of 10 and 40 years respectively). In the proportional (to value) term, this estimates at about 2.0% and 6.6% respectively. The damage from a 5 year and a 20 year flood amounts to about 1.34% and 2.15% of value respectively. It is evident that the damage to roads in a 2 year flood is not considerable, estimated as 0.11% only.

Evidently, the Pourasava roads are the most affected ones, suffering damage in the range of 4.5% and 14.8% of value in the two major floods respectively. The damage to the R & H roads are much less, compared to the Pourasava roads, estimating at 0.75% and 2.0% of their value in the 1987 and the 1988 flood respectively. The other roads, which include the District Council and private roads, suffer damage in the range of 1.4% and 4.4% of their value in the two floods respectively.

The estimates for the physical flood damages to roads for the 1987 and the 1988 flood are fairly satisfactory, as the deviations from the trend for these two major floods are adequately discernable. For the flood years with 2, 5 and 20 year return periods, however, the estimates can be regarded as crude as the data available for the trend analysis have not included the floods of these magnitudes. The estimates could be improved if the analysis was based on a time series data over a longer period, so that the relationship of the deviations from the trend with the corresponding flood levels could be more significant.

Table 6.5: Results of estimated trend on repair costs of R & H roads,1983/84-1992/93

Value in 000 TK, £ = TK 65(App)

Year	Total budget on repair costs	Per Km repair cost (at current price)	Per Km repair cost (at 92/93 price)	2 Yr moving average	Deviation from trend estimated
1983/84	10600	112	190	-	-
1984/85	13400	141	216	203	-38
1985/86	12700	134	188	202	-21
1986/87	13900	146	191	190	-16
1987/88	19500	205	273	232	42
1988/89	22300	234	289	281	106
1989/90	12500	100	116	203	41
1990/91	8300	87	96	106	-43
1991/92	15900	167	170	133	-5
1992/93	5900	62	62	116	-11

Note

:Budget on repair costs compiled from R & H Division office;

:Conversion of repair costs at constant (92/93) price used deflators for construction materials;:see Table C3 (Appendix C);

:Trend equation estimated is of semi-log form: $Y = A' e^{BX} U'$ Or, $\text{Log } Y = A + BX + U$

Table 6.6: Results of estimated trend on repair costs of *Pourasava* (Municipality) roads,1983/84-1992/93

Value in 000 TK, £ = TK 65(App)

Year	Total repair costs	Per Km repair cost (at current price)	Per Km repair cost (at 92/93 price)	2 Yr moving average	Deviation from trend estimated
1983/84	1412	67	113	-	-
1984/85	2425	110	168	141	-114
1985/86	2391	104	146	155	-50
1986/87	2013	84	110	128	-37
1987/88	6318	253	337	224	92
1988/89	7542	290	358	348	242
1989/90	726	27	31	195	110
1990/91	1225	44	49	40	-29
1991/92	337	12	12	31	-24
1992/93	1600	53	53	33	-11

Note

:Repair costs compiled from *Pourasava* (Municipality) office;
:In addition to normal repair expenses, repair costs include a 3 year rehabilitation/repair project (due to 1987 and 1988 flood), amounting to TK 17 Million, out of which TK 12.5 Million was spent on repair work;

:Conversion of repair costs at constant (92/93) price used deflators for construction materials:see Table C3 (Appendix C)

:Trend equation estimated is of semi-log form: $Y = A' e^{BX} U'$ Or, $\text{Log } Y = A + BX + U$

Table 6.7: *Pucca* roads subject to flooding in various floods

Major roads	Per Km cost of construction at 92/93 price (000TK)	Total lengths of roads in town (Km)	% of roads flooded in various floods				
			1988 (40 yr) flood	1980 (20 yr) flood	1987 (10 yr) flood	1984 (5 yr) flood	1993 (2 yr) flood
R & H roads	4200	18	100	100	94	80	16
Pourasava roads (Municipality)	1700	30	100	100	100	95	33
Total	2638	48	100	100	98	89	27

Source : Extent of flooding of roads, compiled from land-use and -level survey (Chapter 7).

: Cost of construction for R & H roads, estimated from World Bank (1982) as reported in Jansen et al (1989) = TK 5.8 Million per mile (88/89 price)=TK 4.2 Million per Km (at 92/93 price);

: Cost of construction for *Pourasava* roads are estimated from quotation bids of various years and averaged on deflating at constant 92/93 price : 10% contractors' gross margin assumed.

Table 6.8: Direct damage to *pucca* roads in various floods

Major roads	Lengths (Km)	Direct damage in various floods (000TK)				
		1988 (40 yr) flood	1980 (20 yr) flood	1987 (10 yr) flood	1984 (5 yr) flood	1993 (2 yr) flood
R & H	15	1272	566	474	293	8
% of value	-	2.02	0.90	0.75	0.47	.01
Pourasava	30	7530	2285	2220	1497	148
% of value	-	14.76	4.48	4.35	2.94	0.29
Other roads	16	2686	911	845	555	44
% of value	-	4.42	1.50	1.39	0.91	0.07
Total	61	11488	3762	3539	2345	200
% of value	-	6.57	2.15	2.02	1.34	0.11

CHAPTER 7: APPLICATION AND TESTING OF APPRAISAL METHODS - TANGAIL CASE STUDY TOWN

7.1 Introduction

This Chapter is a case study analysis. It demonstrates the application of the generated flood loss data sets and assessment methods through providing an example of actual appraisal of a flood protection proposal in Bangladesh. The chapter uses the average damage data sets for various sectors of the urban economy, as an input into the unit-loss model to subsequently estimate the expected benefits of flood protection in Tangail town[102].

7.2 Appraisal Process for Tangail Town

The unit-loss appraisal model aiming at assessing expected annual damage (or the benefits of protection) involves four basic components: (1) potential depth-damage data sets (2) land use of properties (3) level of properties and (4) stage-frequency analysis. With the first step, that is the depth-damage data sets having been constructed, the next essential component of the model is the land use and level survey, which is discussed in the following section.

7.2.1 Land Use and Level Survey

A detailed land use and land level survey was undertaken for each of the individual properties within the Tangail town. The survey was concerned with providing necessary data for various existing properties in the urban economy. No interview was conducted, but the survey was carried out from an external assessment in accordance with a pre-designed check list.

7.2.1.1 Survey Procedure and Methodological Aspects

An explicit definition of the flood prone area is fundamental to the assessment of urban flood damage. In order to define flood limits and the limits for mapping of flood prone properties, the research adopts the conventional definition of a town (used in Bangladesh) to include the benefit area. The town is defined as the total municipal area, the area of boundary where

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[102] The unit loss model is described in Chapter 2.

residents pay P*oura* tax (municipality/urban tax). The definition provides a definite boundary of the area and flood prone properties. As is revealed later in the section on the hydrological survey, about 95 per cent of all the properties in the town are flooded in a 40 year flood. In other words, almost all the properties in the town are likely to be at flood risk in the events with higher than a 40 year return period.

The survey was conducted on every property in accordance with a check list incorporating basic information, such as location, road name (by which properties are situated), levels of roads and sub-roads, land use type, construction type, ground level and floor heights of properties (see Check list: Appendix H). Only the ground floor properties are recorded. Separate record sheets are used for the individual six wards of the town.

7.2.1.2 Land Use Code

One of the main aims of the land use survey is to classify the properties into classes for which stage-damage curves are constructed. Hence the coding system of the properties in the land use survey essentially followed from what was adopted in the sample survey. The land use survey classifies properties into the five major sectors: residential, business, industry, office and roads.

Because of the lack of appropriate maps, no grid references as to the location of the properties were made. Instead, each of the main roads by which the properties are located, were identified as the references for the location of the individual properties. The 47 main roads (all of *pucca* type[103]) were coded separately. The sub-roads of the main roads, however, were not coded. Following the groupings in the sample survey, the residential properties (Sector 1), were grouped into four broad categories according to major construction materials used: BB, BC, MC and MM (as explained in Chapter 4). The business premises (Sector 2) were coded according to 7 broad groups, the industrial units (Sector 3) were coded into 5 broad groups, as discussed in relevant chapters. Likewise, the office and public building sector (Sector 4) were coded in accordance with 5 broad groups.

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[103] The type of roads that are made of concrete/cement (CC) or rod/concrete/cement (RCC)

7.2.1.3 Level and Height survey

Information on the land level and height of properties are of key importance to the precision of flood damage assessments. However, the level and height information of properties were not available from any previous study. Following that detailed and recent contour maps showing contours of roads (by which properties are located) are lacking, a level and height survey was carried out, which aimed at estimating the floor and ground heights of each property in relation to the datum line used for flood records.

The principal steps for measurement of floor heights and land levels of properties are shown in Figure 7.1. The level and height survey was beset with several problems. The major problem relates to the large number of properties under investigation, compared to relatively meagre resources available. In view of the time and resource constraint, the level survey was carried out with some simplifications. First the 47 main roads were identified, by which the sub-roads and the properties are situated. The levels of the main roads were physically measured (in relation to the PWD Bench Mark) by employed surveyors with the help of level measuring instruments[104].

The measurements relating to levels of sub-roads (in relation to main roads) and the ground levels of the properties (in relation to sub-roads) were made through mainly eye estimation. The floor heights of the properties (in relation to the ground levels) were estimated also mostly through eye estimation, although a few cases selected at random were cross-checked through actual measurements to give accuracy improvements. The study area has no properties with any basement used for storage or any other purpose.

The distinctly visible mark of the 1988 flood, still existing at some points of roads and external walls of houses often helped assessment of the levels of sub-roads and properties more accurately. The main roads and sub-roads (under each of the main roads) and subsequently the floor heights, having been related to the PWD Bench Mark, each of the properties were thus linked with the flood records of the gauging station.

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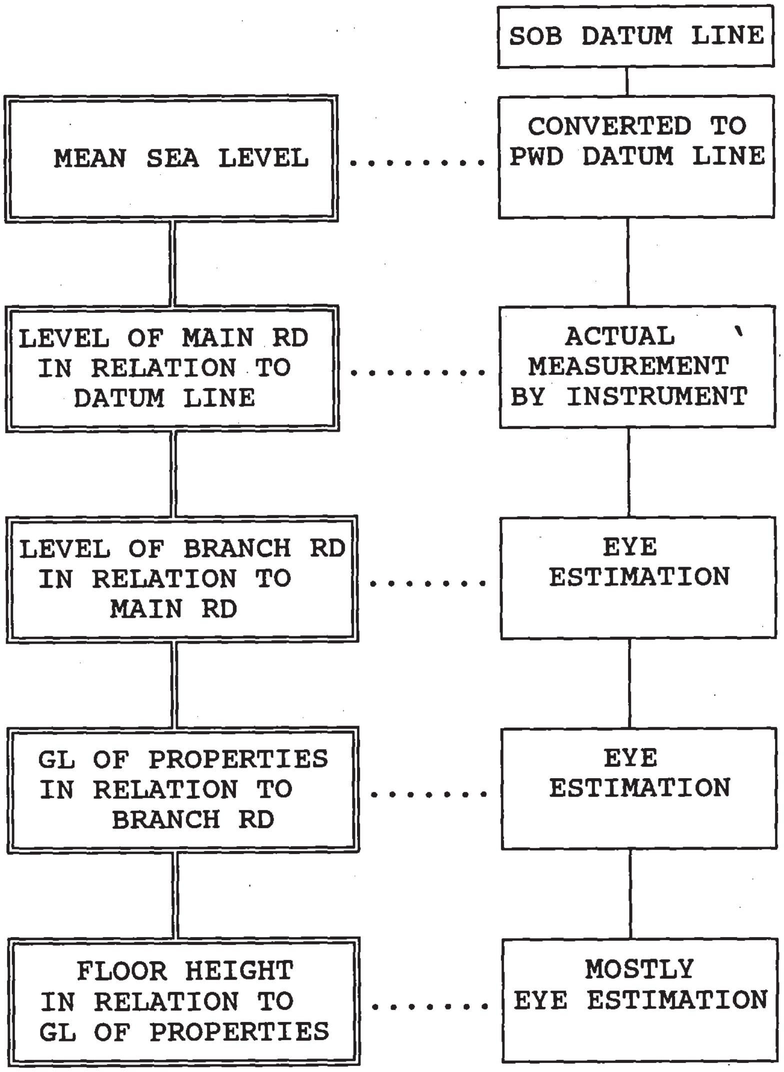
[104] The Bench Mark (0 Datum line), BM-636, is located at a place, 3 ft below ground level and 16 ft north-west corner of the main building of Shibnath High School. The BM-636 set by the Geo-technical Survey of the Survey of Bangladesh (SOB) has the reading of 32.22 ft, which when converted to PWD Bench Mark estimates as 32.22 ft + 1.51 ft =33.73 ft = 10.28 metre. The flood records at Jugini gauging station are available in PWD Bench Mark.

Figure 7.1 : Principal stages and methods of land level and floor height survey



GL - GROUND LEVEL
SOB - SURVEY OF BANGLADESH
PWD - PUBLIC WORKS DEPARTMENT

7.2.1.4 Methodological Problems

The land use and level survey is a major and vital component of the current field research. The level data obtained at different stages are likely to be sensitive in that small errors can lead to compounded inaccuracies in the flood levels of the individual properties and hence their damage assessments. The non-availability of maps (ideally at a scale which could identify each property), lack of grid references leading to failure to locate properties, depressions, byflows and culverts are among the factors having a bearing on the precision of the results. Besides, the properties are not located in a systematic manner or zones. The use of videos in the survey (as often practised in advanced countries) is currently not feasible.

Particularly the work of the physical measurement of the Reduced Levels (RL) of the main roads appears to be sensitive and problematic. The use of average RL of the main roads for the references to the properties is likely to lead to considerable errors, as given the large variations in RLs of the individual roads the averages are not expected to give true levels of the irregularly spaced individual properties along the roads. Thus, ideally the RLs need to be measured at the shortest possible distances in order to minimise errors[105].

The cost of the survey appears to be a limitation. In view of the large number of properties, the clusters of properties having approximately the same floor heights and same ground levels were pooled together and recorded in the booking sheets under one entry. Indeed, the survey was facilitated by that many properties, such as small isolated house groups (e.g MC and MT house types, often owned by extended families - *gusti)*, and business units, located in blocks (e.g. in shopping markets) have approximately the same floor and ground heights.

Because of the lack of appropriate maps, again, the calculation of floor space by means of a systematic grid overlay (as usually practised in Australia or UK) is not feasible. Hence, at the risk of some errors, there is no alternative to the use of the sample floor space for the groups of properties. However, this appears to be not unreasonable, as the survey procedure adopts the random sampling technique.

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[105] The current survey carried out the measurements mostly at distances ranging from 30 to 50 metres.

7.2.1.5 Results of the Land Use Survey

Number of Properties

Tangail town is estimated to have 28,918 properties. Residential properties account for about 82% of the total, followed by business units constituting about 11%, industries about 6% and office constituting 1% of the total properties. Of the six wards, ward 2 (Betka) has the highest number of properties (27%), and the ward 6 (Kazipur) has the lowest number of properties (9%) (Table 7.1).

Table A7.1 shows the distribution of residential houses by construction type. It is evident that the poorest construction type, MT (mud floor with thatched wall) is the most common (35%) and the least common is the MC type (mud floor with CI sheet wall) accounting for about 19%. The houses of higher socio-economic classes, that is, BB (brick floor with brick wall) and BC (brick floor with brick wall) categories constitute 24% and 22% of the total residential properties respectively. It appears that there is an association between ward and type of houses (X^2 value is significant).

7.2.1.6 Floor Heights of Properties

Table A7.2 represents floor heights and Reduced Level of properties (at floor height) by sectors and wards. It is evident that on average a residential house has a floor height of 27 centimetres. Within the residential sector, the poorer house types (MT and MC) have the lower floor heights, both types having an average 19 centimetres, while the richer house types (BC and BB) have the higher floor heights, 36 and 28 centimetres respectively. Of all the sectors, the office and public building sector has the maximum floor height of 36 centimetres, and business units have the minimum, 19 centimetres. It appears that there is a significant association between floor heights and construction type within the residential sector. The association between floor heights and the four sectors is also found to be significant (X^2 values for both the cases are statistically significant).

7.2.1.7 Reduced Levels of Properties

As regards Reduced Level (RL) of properties at floor height, the residential houses are estimated to have the lowest RL, 11.6 metres, followed by the business units having 11.9

Table 7.1 : Number of properties by major sectors by wards

	Number of properties				
	Sectors				
Wards	Residential	Business	Industry	Office	Total
Ward 1 (Central)	3906	1597	583	28	6114 (21.1)
Ward 2 (Betka)	6614	635	377	109	7735 (26.7)
Ward 3 (Zila Sadar)	4752	153	110	103	5118 (17.7)
Ward 4 (Dighalia)	3622	493	298	39	4452 (15.4)
Ward 5 (Santush)	2497	138	148	45	2828 (9.8)
Ward 6 (Kazipur)	2167	177	291	36	2671 (9.2)
Total	23558 (81.5)	3193 (11.0)	1807 (6.2)	360 (1.2)	28918 (100)

Note :

Properties are ground floor properties.

metres, the industries having 12.0 metres and office having the highest RL, about 12.4 metres (Table A7.2).

Table 7.2 shows the percentage of properties at various range of Reduced Levels. The table shows that the distribution of RL has a systematic pattern, which tends to follow a normal distribution. The modal value of the range of RL for all the properties combined is 11-11.5 metres, while the modal value for the residential buildings is the range 11.5-12.0 metres. About two thirds of all the properties are situated at RL 11.0-12.0 metres (Table 7.2).

7.2.2 Hydrological Survey and Frequency Analysis

The fourth essential component of the benefit assessment is hydraulic and hydrological data. However, detailed level hydraulic and hydrological survey is not contemplated; instead the research concentrates on collecting information on flood levels. This is not just because this component of the research relates to hydrology and engineering, but because Bangladesh has scarce records on aspects such as flood discharge, velocity and duration for most of the urban locations.

7.2.2.1 Flood Level Frequency Analysis

Because flood discharge data are not available, flood level information were used in carrying out the frequency analysis. The information on flood levels were collected from the Water Development Board (Tangail) for a 38-year period, 1952 through 1994, with information missing for 5 years. The flood levels are available for the gauging station, Jugini, which is located at the mouth of the Lohajang river and connected with a fixed reference level (PWD Bench Mark).

The results of the flood level frequency analysis are shown in Table 7.3. The average flood level at Jugini gauging station is 12.33 metres with a standard deviation of 0.51 metres. The danger level for the Tangail urban areas is reported to be 12.04 metres, the level which is reported to have been exceeded in 25 events during the 38-year period. The estimated return periods and the corresponding probabilities are shown in the table. The recent flood years were 1980, 1984, 1987 and 1988 with approximate return periods of 20, 5, 10 and 39 years

Table 7.2 : Percentage of properties at various range of Reduced Levels (at floor height)

Range of RL (Metres +PWD)	% of houses					% of units			ALL PROPERTY
	Type					Business	Industries	Office	
	1	2	3	4	All				
≤ 10.5	1.9	2.9	4.2	4.4	3.4	-	0.2	1.3	2.8
10.5-11.0	4.5	7.7	16.8	23.0	14.0	4.3	6.1	4.2	12.3
11.0-11.5	27.9	33.3	32.2	30.2	30.7	40.6	38.5	24.7	32.2
11.5-12.0	46.4	39.1	29.5	23.0	33.4	18.0	27.1	38.4	31.4
12.0+	19.3	17.0	17.3	19.4	18.5	37.1	28.1	31.4	21.3
No of properties	5677 (100.0)	5216 (100.0)	4453 (100.0)	8212 (100.0)	23558 (100.0)	3193 (100.0)	1807 (100.0)	360 (100.0)	28918 (100.0)

Note :

Properties are ground floor properties.

Table 7.3 : Frequency analysis for maximum 3 day mean water level (1952-1994) at Jugini station

Year	Level metres + WDB (L)	Rank (m)	Return period (Tr)	Per cent probability (P)
*1952	12.16	23	1.70	58.8
*1953	12.23	21	1.86	53.8
*1954	12.89	5	7.80	12.8
*1955	13.00	3	13.00	7.7
*1956	12.31	18	2.17	46.1
*1957	12.77	9	4.33	33.11
*1958	12.87	6	6.50	15.4
1959	-	-	-	-
1960	-	-	-	-
1961	-	-	-	-
1962	-	-	-	-
1963	-	-	-	-
*1964	12.86	7	5.57	18.0
*1965	12.53	12	3.25	30.8
*1966	12.76	10	3.90	25.6
*1967	12.44	15	2.60	38.5
*1968	12.62	11	3.55	28.2
*1969	12.23	21	1.86	53.8
*1970	12.48	14	2.79	35.8
*1971	12.08	24	1.63	61.3
1972	12.02	26	1.50	66.7
*1973	12.24	20	1.95	51.3
*1974	12.44	15	2.60	38.5
1975	11.81	28	1.39	71.9
1976	11.59	33	1.18	84.7
*1977	12.20	22	1.77	56.5
1978	11.41	34	1.15	87.0
1979	11.71	31	1.26	79.4
*1980	13.14	2	19.50	5.1
1981	11.76	30	1.30	76.90
1982	12.04	25	1.56	64.1
*1983	12.51	13	3.00	33.3
*1984	12.80	8	4.88	20.5
*1985	12.40	16	2.44	41.0
1986	11.71	31	1.26	79.4
*1987	12.95	4	9.75	10.3
*1988	13.41	1	39.00	2.6
1989	11.60	32	1.22	82.0
1990	11.93	27	1.44	69.4
*1991	12.39	17	2.29	45.7
1992	11.78	29	1.34	74.6
1993	12.26	19	2.05	48.8
1994	11.22	35	1.11	90.1

n = 38 ; average level = 12.33 m; st deviation = 0.51 m; Range = 2.19 m; Rerun period Tr = (n+1)/m; Per cent probability p% = 100/Tr

Danger level = 12.04 m (according to Jugini gauging station)

* Year of crossing danger level, according to Bangladesh Water Development Board, Tangail.

respectively. The 1988 flood is estimated to have the highest return period of 39 years, associated with the corresponding probability of 2.6%[106].

The analysis indicates that the difference in levels between floods of different return periods is not large. However, given the topography of the Tangail urban area, even such small differences in levels can be significant in terms of area affected and damage caused. As an extreme example, the difference in level between a 2 and a 5 year flood is about 50 centimetres, while the properties flooded by these two types of floods are 19 and 73 per cent respectively (Table 7.5).

7.2.2.2 Slope Factors - Water Surface Gradient

Tangail town, situated in the young Jamuna floodplain, is in the north central region of Bangladesh. The Dhaleswari river (which originates from the Jamuna river), and its distributary, Lohajang (which passes through the town) is the main source of flooding in the town. The flood level records are based on a single gauging station, which is not situated in the community, but about 13 Km upstream of the main town. The river surface normally has a significant downstream gradient. The properties located in the downstream are thus likely to have lower flood levels than those around the gauging station in the upstream. The level differences are likely to be lower if the flood gradient is steep (e.g. in the larger floods with higher intensities), and when the properties are irregularly spaced along the river valley. The interventions by depressions, canals, culverts, roads and embankments are also likely to contribute to the variations in water levels in the urban areas.

The Compartmentalization Pilot Project (CPP-Flood Action Plan 20) has estimated a mean difference in level, -33 cm, linking the water level (of monsoon 1991) of Jugini gauging station with one of the compartments (SC-16). However, the SC-16 compartment is only a small part of the Tangail town, while the town in the current research, is defined as the whole municipal area. The mean level difference, -75 cm, between Jugini gauging station with all the 15 compartments (excluding SC-16), estimated by CPP also appears to be inappropriate for the present purpose. The use of mean level difference for the purpose of damage assessment can be misleading in that it is quite likely that the 47 different roads will have

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[106] The return period for the 1988 flood in other parts of the country ranges up to 100 years.

completely different flood levels.

Hence, an indirect way of estimating gradients of river surfaces is adopted. First, the mean depths of inundation in the 1988 flood for each of the main roads are estimated from several observations at various points[107]. The flood marks (which are often still distinct on the house external walls) and discussions with the residents helped accomplish this. Having known the RLs of the individual roads from the physical measurements, the slope factors for each of the roads can be estimated through linking these with the 1988 flood level at the gauging station. Hence, let Dr be the mean 1988 flood depth of r-th road and Rr be its RL. Then gradient or the slope factor, Sr, of the r-th road is given by Sr = Lj - (Dr + Rr), where Lj is the 1988 flood level at the Jugini gauging station. The slope factors for the 47 main roads along with their mean Reduced Levels and mean depths of inundation (1988 flood) are shown in Appendix Table A7.3. As can be seen, the average slope factor for the main roads in Tangail estimates as 1.02 metre, with a standard deviation of 0.38 metre and range 1.82 metre. The mean RL of the roads is estimated to be 11.35 m + PWD and the mean depth of flooding across all the roads is estimated to be 0.88 metre.

7.2.2.3 Vulnerability of Properties and Wards to Flood Events

Table 7.4 shows the percentage of properties flooded at floor heights by floods of various magnitude. It appears that Tangail town is a considerably flood prone area. It appears that in a 2 year flood, about 19% of all the properties are inundated, followed by 73% in a 5 year, 83% in a 10 year, 91% in a 20 year and 95% in a 40 year flood. As regards the land uses, the residential properties appear to be relatively more vulnerable and the business sector appears to be relatively less vulnerable to flooding. Table 7.5 presents information on vulnerability of wards to flooding of various magnitudes. Graphical representations of vulnerability of properties and sectors are shown in Appendix Figures A7.2 through to A7.9.

7.3 Assessment Methods and Flood Loss Data Sets

The assessment methods and flood damage data sets used in the estimation of flood losses in Tangail town are briefly outlined in Table 7.6. The study concerns intangible damage, direct

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[107] It could be ideal, however, if for more than one flood, rather than only 1988 flood, could be contemplated.

Table 7.4 : Percentage of properties flooded (above floor) by floods of various magnitudes

Flood magnitude	% of total houses flooded					% of commercial units flooded			ALL PROPERTIES
	Type								
	1	2	3	4	All	Business	Industries	Office	
2 yr flood	11.9	16.1	24.6	28.4	21.0	4.7	11.7	13.6	18.5
5 yr flood	72.0	74.5	79.8	80.1	76.9	52.5	60.5	53.6	72.9
10 yr flood	85.9	81.6	86.9	86.3	86.4	66.4	71.2	64.7	83.0
20 yr flood	94.0	94.6	93.4	91.2	93.1	79.7	81.1	81.4	90.7
40 yr flood	96.8	97.1	96.8	95.2	96.3	86.7	88.5	88.9	94.7
No of properties.	5677 (100)	5216 (100)	4453 (100)	8212 (100)	23558 (100)	3193 (100)	1807 (100)	360 (100)	28918 (100)

Table 7.5 : Flood proneness of Tangail town by wards (flooded above floor of properties) by floods of various magnitudes

	All properties (Residential/business/industrial/office units)						
Flood type	Ward 1	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Total
<u>2 Year Flood</u>							
% at risk	9.7	22.9	39.8	8.5	26.6	26.4	18.5
<u>5 Year Flood</u>							
% at risk	67.2	73.0	75.8	73.0	79.7	75.4	72.9
<u>10 Year Flood</u>							
% at risk	83.1	85.0	83.3	81.0	87.1	83.2	83.0
<u>20 Year Flood</u>							
% at risk	94.4	92.5	92.3	85.2	90.6	89.7	90.7
<u>40 Year Flood</u>							
% at risk	97.5	96.5	97.3	88.6	93.0	93.9	94.7
Total no of properties	6114 (100.0)	7735 (100.0)	5118 (100.0)	4452 (100.0)	2828 (100.0)	2671 (100.0)	28918 (100.0)

Table 7.6 : Flood loss data and assessment methods used in the estimation of urban flood damage in Tangail town

Sector/land use	Damage data used	Broad methods/assumptions
ALL SECTORS	Depth-damage data, except for roads sector, and for 'other' damage component in residential sector	Average group depth damage data are constructed for all sectors at 92/93 price, through regression methods; 2 & 5 yr flood use short duration data; 10, 20 & 40 yr flood use both short & long duration data, based on corresponding sample proportions in each category. Sample floor space used to estimate total floor space, except for office sector. Structural damages for all sectors assumed no damage-reduction measures. Inventories/stock/machinery/equipment adjusted for damage-reduction activities.
1 Residential	Proportional depth-damage data : direct damage	Average group proportional (to value) depth damage data (by individual damage components). Structural damage considers 'all structures'. clean-up costs incorporated into structural damages.
	Per household damage data : 'other' direct damage	For 'other' damages (eg livestock, trees etc), no potential data constructed, generalised 'per household'(by house groups) data used for this component.
2 Business	Per sq metre depth-damage data:direct&indirect damage	Business group loss average data (by individual damage components) used. For indirect damage, national damage incorporated. Linkage effects not contemplated; both retail & wholesalers included in the sample.
3 Industries	Per sq metre depth-damage data:direct&indirect damage	Manufacturing group loss average data used by individual damage components. Industries-related services included in manufacturing; for indirect damage, damage to nation incorporated. Linkage effects estimated through input-output method.
4 Office	Per sq metre depth-damage data : direct damage	Office group loss average data (by individual damage component) used. Educational institutions, health and utility services included. Population floor space used.
5 Roads	Per km event-loss data : direct damage	Trend analysis method used;only *pucca* roads,under R&H Div and *Pourasava* authority contemplated. No assessment made for herring-bone and *kutcha* roads
Miscellaneous:		
Agriculture-crops	-	Not incorporated into damage assessment.
Agri building	-	Incorporated into public buildings (Sector 4).
Open space	-	Not incorporated into damage assessment

and indirect. The five major sectors of the urban economy are contemplated. Although agricultural land use is likely to be considerable in a secondary town such as Tangail, the agricultural crop sub-sector is not incorporated in the current analysis. But the agricultural sub-sectors such as livestock, poultry, kitchen gardening and tress are included in the damage assessment.

The group loss average potential data sets (direct loss) for the sectors 1 through to 4 (residential, business, industry and office) are used in the assessments. For the sector 5 (roads), direct damage to two types of *pucca* roads (Pourasava and R & H) are incorporated. For the sectors 2 (business) and 3 (industry), however, indirect damages are also estimated. As the analysis concerns national economic analysis, the indirect losses in the two sectors, industries and business, include losses to nation. The linkage effects of flooding applicable for only industries sector, are included in the total damage assessment.

The damage values at 1992/93 price are used. While inevitably sector loss data or per establishment loss data would be suitable for a desk-level appraisal, the present assessment uses proportional group loss average data for the residential sector, and per square metre group loss average data for business, industries and office sectors. For roads, per kilometre direct loss data are used. For the business and industries land use, total floor spaces are estimated using the group sample means, while for the office and public buildings, population floor spaces obtained from the land use survey are used in the group and total damage assessment.

It has always been a formidable task to incorporate duration in the damage assessment, as it is not known which properties in the future will be inundated with which durations. While the potential relationship between depths and durations could be useful, significant association among the sample units is not found. In the assessment, thus, duration is taken into account through adopting a broad assumption. Large floods such as those with 10, 20 and 40 year return period (equivalent to 1987, 1984 and 1988 flood) are assumed to involve both category of durations (up to 7 days and 7 + days). Since the survey resorts to random sampling technique, it is fairly reasonable to use the proportions of the corresponding sample units in the two category of durations. For the 2 and 5 year flood events, however, uses are made of only the short duration data (up to 7 days).

7.4 Application of the Unit-loss Model

The unit-loss model is described in Chapter 2. The group loss average potential data sets are imputed into the unit-loss model to achieve estimates of total event and sector loss. Five hypothetical flood events are considered: 2, 5, 10, 20 and 40 year flood. The direct, primary indirect and linkage effects are contemplated. The direct damage includes the components, structure, inventory, machinery/equipment (where applicable), and the primary indirect damage includes loss to value added/gross margin and the multiplier effects include the linkage effects (where applicable).

7.4.1 Computation and Results

The computations are performed by SPSS. Ideally, the computations of sector/event losses could have been accomplished by ESTDAM, the software package developed and used by Flood Hazard Research Centre. The benefit assessment through the ESTDAM package is particularly efficient in that it automates the process of calculation by incorporating the property grid references used to locate each and every individual properties in the benefit area, a feature which is otherwise difficult. Besides, ESTDAM typically incorporates the effects of interventions such as depressions and bypass flows at various locations of the benefit area. The package is far more efficient for carrying out sensitivity analysis through an iterative procedure.

However, ESTDAM has limited use if the properties in the benefit area are more than 20,000, which is frequently the case with many small towns in Bangladesh. The number of properties in the current benefit area, for example, is around 29,000. Given that the current land use and level survey has not incorporated the grid reference of properties, depressions or byflows, the use of the ESTDAM software is not likely to add anything to the precision of the benefit assessment. The other reason for not using the package is that it is not commercially available, so that for Bangladesh the use of SPSS is more worthwhile. SPSS estimates the number of properties, by type or group in each sector that are flooded by each depths of flooding at each flood frequency. Through incorporating the group average depth-damage data sets for individual group and damage component, total damages for each flood events/sectors are assessed.

Table 7.7 shows the damages by sectors and loss components predicted in floods of

Table 7.7 : Estimated potential damage in floods of different return periods : Tangail town

Damage value in 000 Taka : 92/93 price : £ = Taka 65 (approx)

Flood	Sector	Direct damage			Indirect damage		TOTAL
		STRUCTURE	INVENTORY /STOCK	MACHINERY /EQUIPMENT	PRIMARY INDIRECT	LINKAGE EFFECTS	
2 YEAR	Residential	11521	48403	-	-	-	59924
	Business	239	4660	-	2155	-	7054
	Industries	855	5260	2368	7036	4299	19818
	Public buildings	1615	-	1560	-	-	3175
	Roads	200	-	-	-	-	200
	TOTAL	14430	58323	3928	9191	4299	90171
5 YEAR	Residential	48583	207406	-	-	-	255989
	Business	3514	71704	-	25859	-	101077
	Industries	5050	31332	13580	39496	24128	113586
	Public buildings	3082	-	4720	-	-	7802
	Roads	2345	-	-	-	-	2345
	TOTAL	62574	310442	18300	65355	24128	480799

Table 7.7 :(contd)

Damage value in 000 Taka : 92/93 price : £ = Taka 65 (approx)

Flood	Sector	Direct damage			Indirect damage		TOTAL
		STRUCTURE	INVENTORY /STOCK	MACHINERY /EQUIPMENT	PRIMARY INDIRECT	LINKAGE EFFECTS	
10 YEAR	Residential	109152	362878	-	-	-	472030
	Business	5266	112213	-	37601	-	155080
	Industries	7092	49551	22088	59273	36210	174214
	Public buildings	4031	-	5502	-	-	9533
	Roads	3539	-	-	-	-	3539
	TOTAL	129080	524642	27590	96874	36210	814396
20 YEAR	Residential	137565	452767	-	-	-	590332
	Business	8378	150986	-	48730	-	208094
	Industries	18968	58524	25293	68406	41789	212980
	Public buildings	6290	-	7092	-	-	13382
	Roads	3762	-	-	-	-	3762
	TOTAL	174963	662277	32385	117136	41789	1028550

Table 7.7 :(contd)

Damage value in 000 Taka : 92/93 price: £ = Taka 65 (approx)

Flood	Sector	Direct damage			Indirect damage		TOTAL
		STRUCTURE	INVENTORY /STOCK	MACHINERY /EQUIPMENT	PRIMARY INDIRECT	LINKAGE EFFECTS	
40 YEAR	Residential	171520	558206	-	-	-	729726
	Business	8185	201561	-	60813	-	270559
	Industries	10359	72147	30363	81783	49961	244613
	Public buildings	6878	-	8152	-	-	15030
	Roads	11488	-	-	-	-	11488
	TOTAL	208430	831914	38515	142596	49961	1271416

Note : Primary indirect loss refers to national output loss, without considering potential decline in demand successive frequencies, ranging from the 2 to the 40 year event. The 1988 flood, the most disastrous event on record in the country has a return period ranging from 40 to 100 year depending on the various locations in the country. In Tangail town, the event has a return period of approximately 40 years. The available hydrological data do not allow including events beyond the 40 year flood.

It is evident from the table that the total urban flood loss predicted in a 2 year flood is about TK 90 million in Tangail town, which increases to about TK 481 million in a 5 year flood, followed by TK 814 million, TK 1029 million and TK 1271 million in a 10 year, 20 year and a 40 year flood respectively. The total losses are disaggregated by the five land use sectors and the five damage components.

The residential sector suffers a flood loss amounting to about TK 60 million in a 2 year flood. The amount jumps to TK 256 million, TK 472 million, TK 590 million and TK 730 million in a 5 year, 10 year, 20 year and 40 year flood.

The business sector incurs a flood loss amounting to TK 7 million in a 2 year flood. The amount estimates to as high as TK 101 million in a 5 year flood, followed by TK 155 million, TK 208 million and TK 271 million in a 10 year, 20 year and 40 year flood.

The industry sector incurs a flood loss amounting to about TK 20 million in a 2 year flood. The amount increases to TK 114 million, TK 174 million, TK 212 million and TK 245 million in the other four flood events respectively.

The office and public buildings sector incurs a relatively a minor flood loss, estimating as 3.2 million in a 2 year flood, followed by TK 7.8 million, TK 9.5 million, TK 13.4 million and TK 15.0 million in a 5 year, 10 year, 20 year and 40 year flood respectively.

The damage (direct damage) to roads infrastructure also estimates at a relatively minor amount. The flood damage to this sector is relatively insignificant in a 2 year flood, amounting to TK 0.2 million. However, the amount sharply increases in the larger floods, to TK 2.3 million, TK 3.5 million, TK 3.8 million and TK 11.5 million in a 5 year, 10 year, 20 year and a 40 year flood events respectively.

Table 7.8 demonstrates the sector analysis, while the Table 7.9 demonstrates the damage

Table 7.8 : Sector analysis of event damages : Tangail town

Damage value : 92/93 price : £ = Taka 65 (approx)

Flood return period	Sector loss (%)					TOTAL EVENT LOSS (000 TK)
	Residential	Business	Industries	Office & Public buildings	Roads	
2 Year	66.5	7.8	22.0	3.5	0.2	90171 (100.0)
5 Year	53.2	21.0	23.6	1.6	0.5	480799 (100.0)
10 Year	58.0	19.0	21.4	1.2	0.4	814396 (100.0)
20 year	57.4	20.2	20.7	1.3	0.4	1028550 (100.0)
40 Year	57.4	21.3	19.2	1.2	0.9	1271416 (100.0)
AVERAGE	57.2	20.1	20.7	1.4	0.6	737066 (100.0)

Table 7.9 : Damage analysis of event damages : Tangail town

Damage value in 000 Taka : 92/93 price: £ = Taka 65 (approx)

	Component damage (%)					
	Direct damage			Indirect damage		
Flood return period	STRUCTURE	INVENTORY /STOCK	MACHINERY /EQUIPMENT	PRIMARY INDIRECT	LINKAGE EFFECTS	TOTAL EVENT LOSS (000 TK)
2 Year	16.0	64.7	4.4	10.2	4.8	90171 (100.0)
5 year	13.0	64.6	3.8	13.6	5.0	480799 (100.0)
10 Year	15.8	64.4	3.4	11.9	4.4	814396 (100.0)
20 Year	17.0	64.4	3.1	11.4	4.1	1028550 (100.0)
40 year	16.4	65.4	3.0	11.2	3.9	1271416 (100.0)
AVERAGE	16.0	64.8	3.3	11.7	4.2	737066 (100.0)

analysis in the various selected events. As is evident from the Table 7.8, averaged over all the five flood events, small, medium and large, the residential sector appears to be the most vulnerable sector in the whole urban economy, accounting for the major proportion in the total urban loss, e.g. about 57%. The proportion of business damage in the total loss on an average amounts to about 20%, while that for the industries account for about 21%. The sector, office and public buildings, constitutes about 1.4% in the total loss, while the sector, roads infrastructure, accounts for 0.6% in the total urban loss.

As can be seen from the Table 7.9, averaged across damage components over the 5 flood events, the damage component inventory/stock accounts for the highest proportion e.g. 65% in the total loss in the urban economy. This is followed by the next highest proportion of damage caused to structure constituting about 16%, primary indirect loss constituting 12%, machinery/equipment about 3% and the linkage effects accounting for about 4%.

7.5 Assessment of Expected Annual Damage

The ultimate output of the unit-loss model is the estimated expected annual damage (EAD), which is equivalent to the expected annual benefits of protection, from which the present value of benefits is assessed. The present value of the benefits is the commonly used single parameter to represent the feasibility of mitigation schemes, by comparing the discounted benefits with the discounted cost of the protection. Two estimates of the present value of the benefits are accomplished incorporating two test discount rates, 10% and 15%, with a hypothetical 50 year scheme life. The BENNAL software (developed by FHRC) is used for these estimates.

7.5.1 Computation and Results

Table 7.10 shows the loss-probability relationship and the expected annual benefits for the Tangail town. The interval benefits with their lower and upper bound are also shown. Thus for Tangail town the expected annual benefit estimates as TK 248 M, with the lower and upper bound estimated as TK 142 M and TK 354 M respectively. The annual overstandard benefit estimates as TK 32 M, so that the total expected annual benefits increases to TK 280M.

Table 7.11 presents the summary table for the present value of benefits at 10 % and 15% test

Table 7.10: Loss probability analysis

Value in million Taka : 1992/93 price

Return period	Exceedance probability	Event loss	Interval benefits		Cumulative benefits		Lower bound	Upper bound
			Annual	Discounted	Annual	Discounted		
1	1	0	0	0	0	0	0	0
2	.50	90	23	228	23	228	0	45
5	.20	481	86	853	109	1081	27	144
10	.10	814	65	644	174	1725	48	81
20	.05	1029	46	456	220	2181	41	51
40	.025	1271	29	288	248	2456	26	32
Total	-	-	248	2456	-	-	142	354

Test discount rate = 10% ; Scheme life = 50 yrs; Overdesign standard = 32 M Taka;

Table 7.11 Summary table for present value of benefits at 10% and 15% discount rates

All values (except for last column) in million Taka : 1992-93 price : £ = 65 TaKa(approx)

Discount rate (%)	Expected annual benefits	Annual overdesign standard benefits	Annual multiplier	Present value(PV) of benefits	PV (including overdesign standard	PV per property (TK)
10	248	32	9.914814	2456	2771	95823 (£ 1474)
15	248	32	6.660515	1650	1862	64389 (£ 991)

discount rates. The present value of benefits of the flood protection at a 10% discount rate estimates as TK 2456 M (approximately £M 37.8 @ TK 65) to the 40 year standard. At a 15% discount rate, the present value of the benefits amounts to TK 1650 M (£M 25.4 @ TK 65).

In other words, assuming 10% as an opportunity cost of money, at least TK 2456 M is the capital sum worthwhile spending on flood protection to the 40 year standard in the Tangail town. This estimate excludes any account of intangible damages. The field survey reveals that a 40 year flood is likely to last up to more than one month, and inundate a large majority of residential houses so that the intangible impacts such as damage to health or lives could be considerable in a flood of this magnitude[108].

The present value of the overstandard benefit estimates as TK 315 M, so that the total discounted value of benefits (at 10%) are computed as TK 2771 M. However, once the overstandard benefits are incorporated giving the total discounted benefits, it is customary to deduct the post-scheme residual damages, potentially arising out of any extreme event of the magnitude higher than the designed standard of protection. For the present appraisal, however, the residual damages are not computed because of the lack of the necessary hydraulic data. In the absence of the adequate hydraulic and hydrological data, thus, both the additional overstandard benefits and the residual flooding are ignored in the present analysis.

The loss-probability table (Table 7.10) also gives the discounted benefits of protection to a range of design standards. Thus the benefit of protecting the town to the 2 year flood standard is estimated as TK 228 M Taka at a 10% discount rate. The estimated benefit jumps to nearly five times as much, to TK 1081 M, for the standard of protection to the 5 year flood, followed by TK 1725 M and TK 2181 M for the 10 year and the 20 year flood respectively.

As displayed in Table 7.11, the estimated present value of benefits per property amounts to TK 95,823 and TK 64,389 at the two discount rates, 10% and 15% respectively, with a 50

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[108] In a flood of this magnitude, 96% of the total households (i.e. 22,616 households) are flooded. The research e.g. Islam (1997a - forthcoming) maintains that floods have a strong influence on the incidence of diarrhoeal diseases. Hence, the flood impacts on health (in terms of diarrhoeal diseases) may be considerable.

years scheme life. The sterling equivalence for these two estimates are £1474 and £991 respectively[109].

Figure 7.2 represents the loss-probability relationship curve, while Figure 7.3 represents annual benefits versus exceedance probability curve for the Tangail town. It is assumed that floods of one year return period cause no damages.

It appears from the Figure 7.2 that the loss-probability curve tends to follow a linear equation. The curve for the smaller floods appears to be relatively steep compared with those for the larger floods. Thus, the marginal losses are relatively less at larger than 10 year floods. In other words, so far as the current benefits are concerned, the standard of protection tends to be optimal at the 5 or 10 year flood. For example, the annual interval benefit appears to be relatively high between the 2 and the 5 year flood (TK 86 M), and the 5 and the 10 year flood (TK 65 M), compared to those for the larger events. The interval benefit amounts to TK 46 M in a 20 year flood, and it estimates as the minimum, TK 29 M, in the case of a 40 year flood. The graphical representation of the interval benefits are shown in the Figure 7.3.

7.6 Probable Costs of Protection

Even though the benefit-cost analysis is beyond the purview of the present study, an estimate of the probable cost of protection for two design standards in the Tangail town is worked out, which facilitates a preliminary comparison with the benefits of protection. The total cost of the protection estimates as TK 173.7 M and TK 186.3 M for standards of protection, 20 and 40 year respectively. However, this figure excludes the operation and maintenance costs, which could be a major cost component in Bangladesh. The cost of the drainage system associated with the flood protection scheme is also excluded. The assumptions and detailed cost structure of the estimates are presented in Appendix D. The cost estimate appears to be too conservative, and thus needs to be treated with much caution.

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[109] Although the results are not strictly comparable, mention may be made here of the present value of benefits per property in a UK urban protection (Lincoln case study), estimated as £3363 (Parker et al 1987, computed at 1985 price at a 5% discount rate, with a 100 year scheme life). Some other estimates are £3239 (1987 price) (Thames Water - Lower Colne Study, FHRC 1987) and £4392 (1986 price) (Westgate Back Flood Relief Scheme, FHRC 1986), both with a 50 year life at 5% discount rate.

Figure 7.2 : Loss probability curve

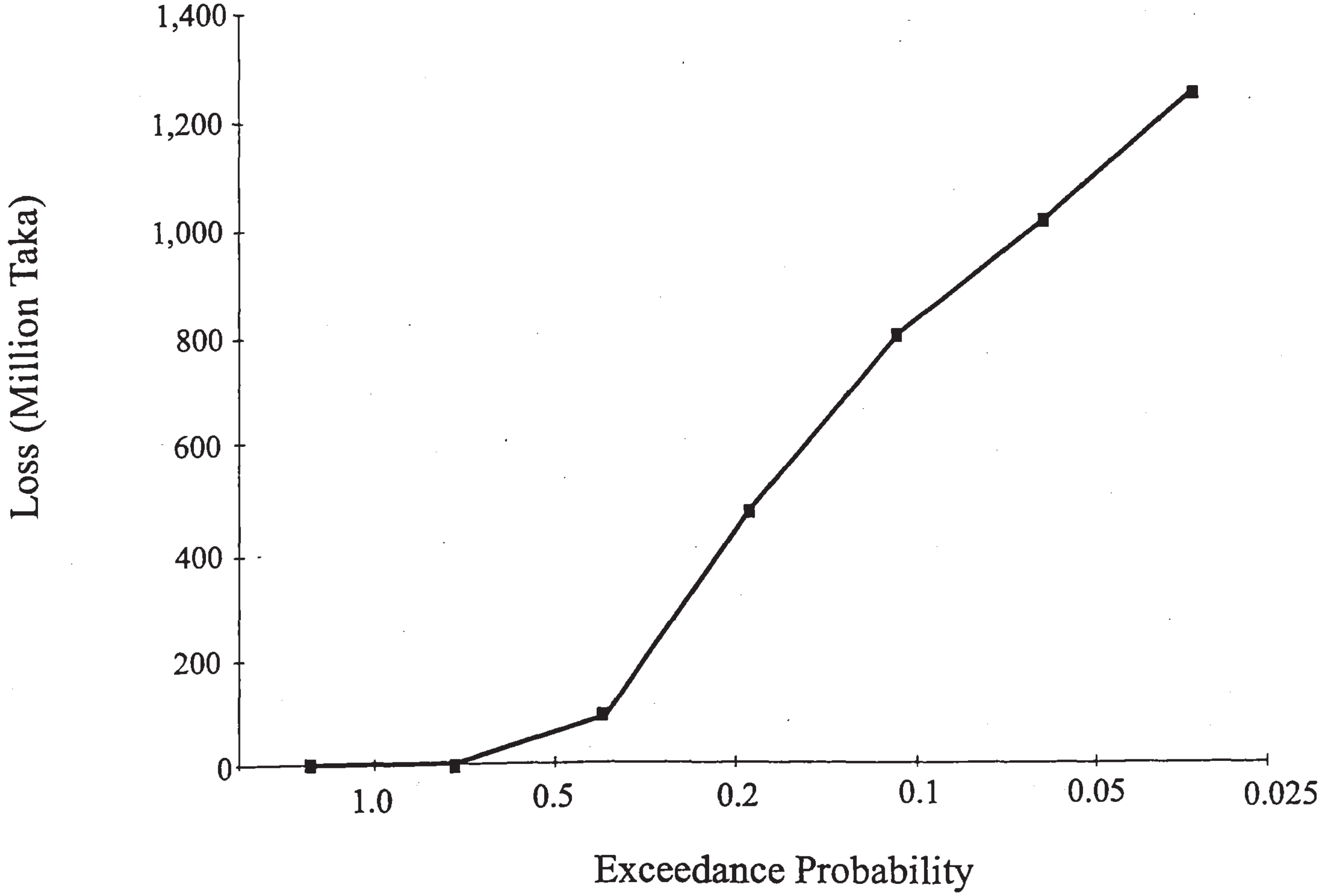
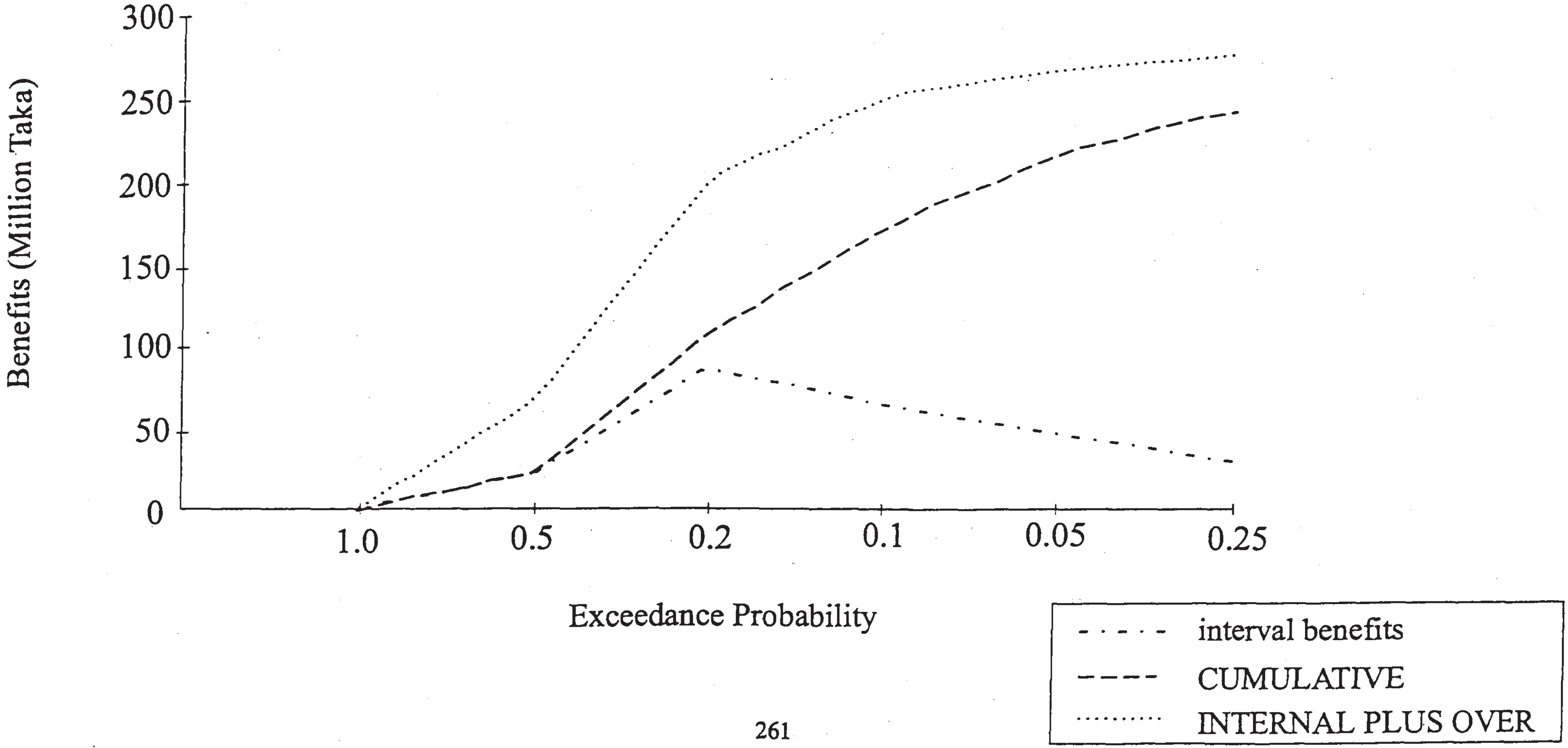


Figure 7.3 : Annual benefits versus exceedance probability curve



CHAPTER 8: LINKAGES AND IMPACTS OF FLOODING AT MACRO LEVEL[110]

8.1 Introduction

The preceding Chapters have addressed the flood loss potentials at the micro level. To summarise, the chapters examined various approaches of flood loss modelling and constructed potential loss data sets in the five major urban sectors. The data sets were subsequently used as an input to the modelling of expected annual damage in the main case study town. In each of the sectors, empirical analyses were carried out designed to explain flood loss variations over damage components, flood types and socio-economic groups of occupants.

It is revealed that the residential sector is the most vulnerable in the whole urban economy, followed by industrial, business and other sectors. Among the direct damages, stock for commercial sectors, and inventory for the residential sector comprises the major damage component in the case of all the flood types. The indirect damage including the linkage effects of flooding in industries appears to be quite high. The empirical analysis reveals that the low-income householders and small-sized commercial enterprises are relatively more vulnerable to floods. On the whole, it is revealed that the potential urban flood losses at the micro level in Bangladesh are high.

This Chapter addresses the research question whether linkage effects at the macro level are important in Bangladesh. Based on time series data at the national level, collected from secondary sources, the chapter seeks to present some evidence of flood impacts at the macro level. The analysis is carried out on two broad sectors of the economy, agriculture and industry[111].

The issue of flood impacts at the macro level and linkages are interrelated. At the outset, thus, the chapter conceptualises briefly various forms of potential linkages that can exist in an economy, and then examines their link with flood impacts.

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[110] Based on this chapter, two research articles are published, one as a Research Report (BIDS, No 146, August, 1996), and the other as a School of Geography and Environmental Management Working Paper, Middlesex University, April, 1997).

[111] Besides, the research presents some evidence of flood impacts on health sector (largely on incidence of diseases), however, not presented here, but can be found in Islam (1997a).

8.2 Delineating Linkages

Flood damages have been categorised as direct or indirect and by whether or not they are tangible (Parker et al 1987). The tangible impacts are those impacts which can be measured, and the intangible ones which cannot be valued in monetary terms. While the direct impacts of flooding are those caused by direct contact with water, indirect impacts of flooding arise from interruption and interaction between various social and economic activities that exist in an economy. In an economy, particularly with an open and perfect market structure, there can be innumerable directions and dimensions to these interactions among various sectors in the form of 'flows' and 'stock'. These inter-sectoral relationships, or linkages as they are usually called, play a crucially important role in the growth of an economy.

The 'flows' and 'stock' in economic variables, such as employment and income, input and output, comprise a category what may be called economic linkages. The spatial linkages include interactions between enclave region (e.g. urban) and hinterland (e.g. rural) in a national economy. Of all the linkages, the linkages related to production, in the form of input and output, serve as the primary vehicle in determining directions and dimensions of other forms of linkages. In production linkages, backward production linkage is the one if the production activity of one sector requires inputs from the other sector, and the forward linkage is the one where production of one sector provides supplies to another. Thus, the forward linkage in one sector is the backward for another. In the broader sense of the term, however, linkages may imply many other interfaces. If a flood, for example, cuts a road which has no alternative route, commuters who are dependent on it have to suffer maximum losses because of lack of 'redundancies', unless they can 'defer'. In Bangladesh, however, such losses are likely to be small during floods, as dependencies on roads are presumably largely offset by 'natural' redundancies created by water-ways through the use of boats. In effect, this linkage is expected to boost the growth of boat-making industry during floods.

The elements of linkages are contained in the concept of 'redundancy', 'dependence' or 'transferability' (Parker et al 1987). Thus, in an economy comprising a linkage network of innumerable 'nodes', the higher the dependencies (or lesser the scope for 'redundancies'), the higher are the flood losses. Likewise, the more the potential for 'transferability' a firm has, the more the scope it has for loss adjustments, and hence the lesser are the potential indirect losses. The flooded retail and, at times, wholesale shops, for example, in Bangladesh often minimise their business losses through creating 'redundancies' by vending at the doorstep of consumers, or through opening mobile shops under the sky in temporary tents, the practice which is similar to the war-time 'business-as-usual' in Great Britain.

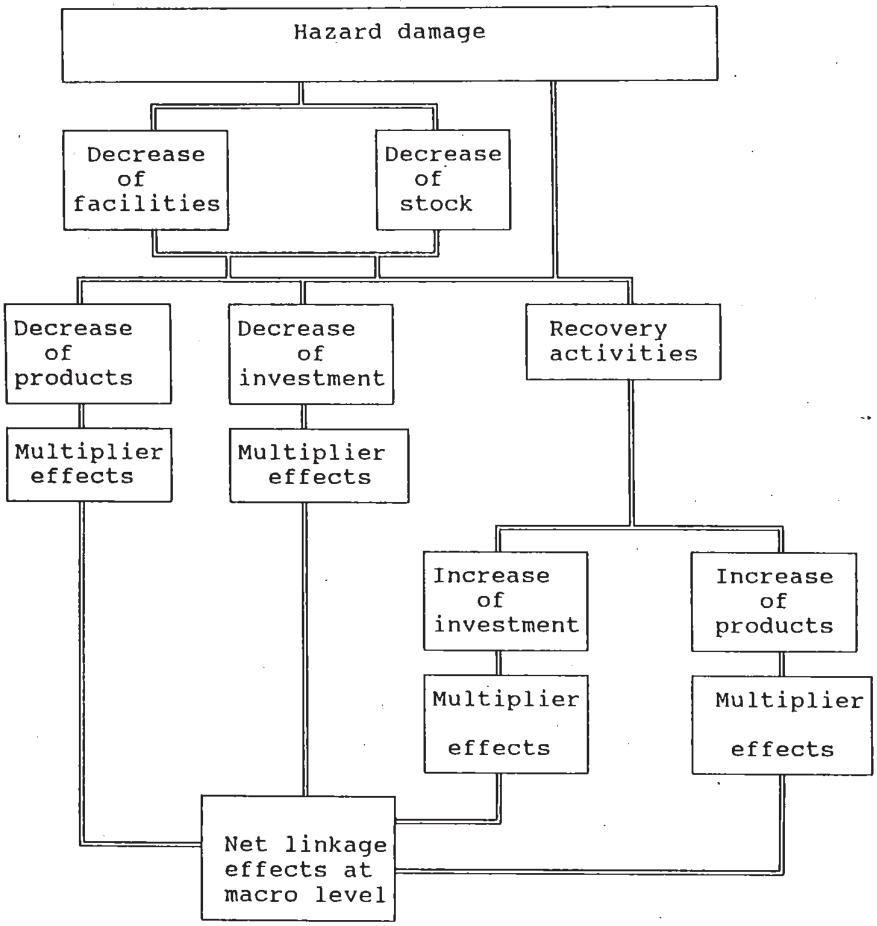
Linkages in an economy are expected to give rise to external economies. If flooding takes place in two or three consecutive years in a protected zone, for example, demand for land and consequently its value is expected to decline abruptly without any economic actions being taken. This is also a type of linkage. Linkages, which usually give rise to dependencies, do not necessarily give rise to indirect losses. For an individual firm, it might cause apparent losses but, in the national or regional context, the link between linkages and losses depends on whether the economy has surplus capacity. If the economy is characterised by under-capacity utilisation some firms can simply utilise their idle capacity and make up the losses to production incurred by others; some firms even operate above their designed capacity, and some firms try to monopolise in the short run to earn extra profits.

Demographic and social characteristics such as community development, friendliness and kinship are also the kind of linkages which are likely to have a bearing on flood losses. Such linkages, however, are likely to act contrary to economic linkages. That is, from the economic linkages point of view, the more the dependence or ties, the more likely are the indirect impacts in the economy. On the other hand, from the point of view of social linkages, the more the community is tied, the stronger would be the response activities and less serious are the impacts. In other words, the more a community is socially linked, the more will be the extent of 'transferability', and, in effect, the less will be the flood losses, for example. Nonetheless, this is more true for direct losses, such as losses to inventories or stock. Hence, linkages have innumerable complex dimensions and directions. The whole process of adjustment to hazards is indeed inter-linked. Hence the issue of linkages is required to be researched in a more broader perspective.

8.3 Flow of Linkage Effects

Linkage effects of flooding arise out of the 'knock on' effect of primary indirect impacts, which again tend to result in chains of secondary and higher order impacts, called multiplier effects. A typical flow of linkage effects at macro level is shown in Figure 8.1. The first major round of linkage effects associated with a flood is the decrease of products, which is primarily due to the effect of the following two factors:

Figure 8.1: Flow of major linkage effects of flood damage at macro level



Net linkage effects (at macro level) = Multiplier effects of decrease of (products + investments) - Multiplier effects of recovery through increase of (products + investments)

a) decrease of products, due to damage to physical facilities (e.g. building, machinery) and functional facilities (e.g. utilities)

b) decrease of products, due to damage to stock (e.g. input, finished and un-finished products)

This decrease of products leads to a decline in investment, which results in a further decrease of products, illustrating the multiplier effect.

The next major round of linkage effects relates to recovery activities, which inevitably increases expenditures on purchase of materials for restoration and thus enhances the level of output and investment, which have positive multiplier effects. Net linkage effects at macro level then work out broadly as follows:

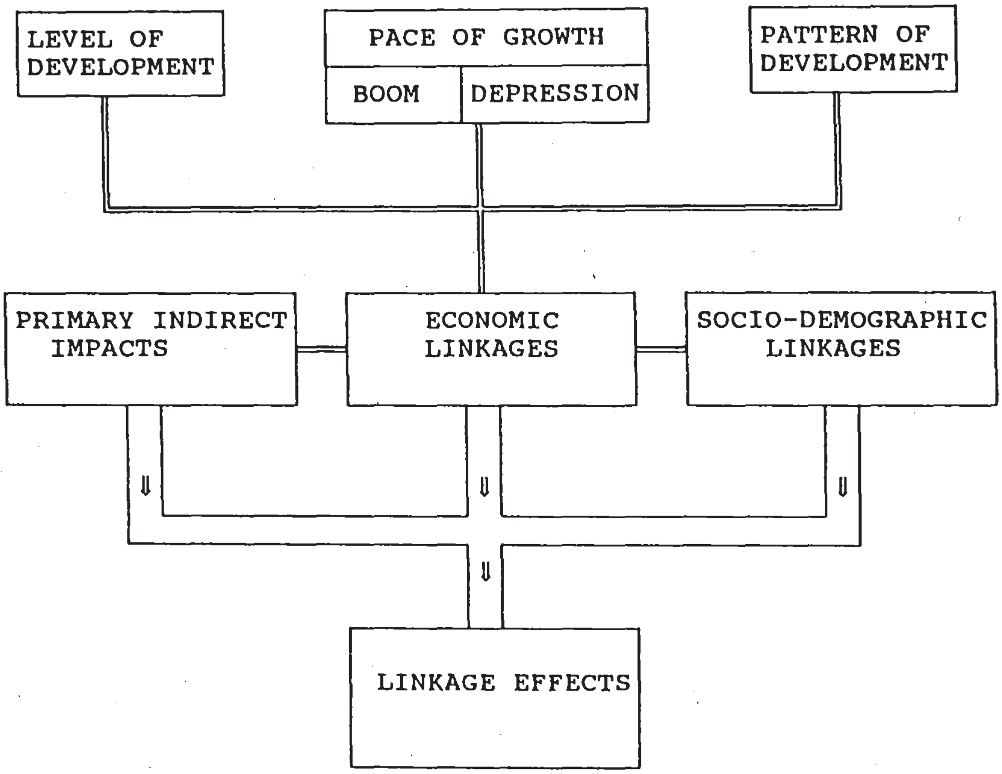
Net linkage effects = Multiplier effects of decrease of (products + investments) - Multiplier effects of recovery through increase of (products + investments).

8.4 Impetus of Linkages

Economic linkages can primarily be related to a few factors in an economy such as (1) level of development (2) pace of economic growth and (3) pattern of development (Figure 8.2). The level of development relates to the state of the economic development, that is whether the economy is in a developing or an advanced state. The pace may be referred to: whether the economy is at a state of boom or depression at a point in time; on which naturally economic linkages are dependent. The pattern of development is one of overall sectoral development. Socio-demographic characteristics such as community ties and dependency ratios (ratio of earners to total household members) may also comprise important determining variables.

Hence, given a level and pattern of development in an economy, and socio-demographic and cultural characteristics in a society at a point in time, linkage effects of flooding are likely to be dependent on the magnitude of primary indirect impacts, on the one hand, and economic linkages that exists in the economy, on the other (Figure 8.2).

Figure 8.2 Major elements and impetus of linkage effects



8.5 A Typical Form of Inter-sectoral Linkages

A typical form of major linkages that is likely to exist in an economy at the macro level is demonstrated in Figure 8.3. For the sake of simplicity, however, only two broad sectors (Agriculture and Non-agriculture) in a closed economy is assumed. Thus, the flow of imports or exports is not exhibited. In a developing country perspective, which is usually characterised by an early stage of economic development, the agriculture sector plays a dominant part in contributing to linkages. As depicted in the figure, the economic interactions are between the two primary supply premises (Agricultural and Non-Agricultural output sectors), on one hand, and the two major demand premises (Agricultural and Non-Agricultural households) on the other. The salient inter-sectoral linkages are merged into four broad types of 'flows': Technological, Capital, Commodity and Employment flows (Ranis et al, 1990).

Technological Flows

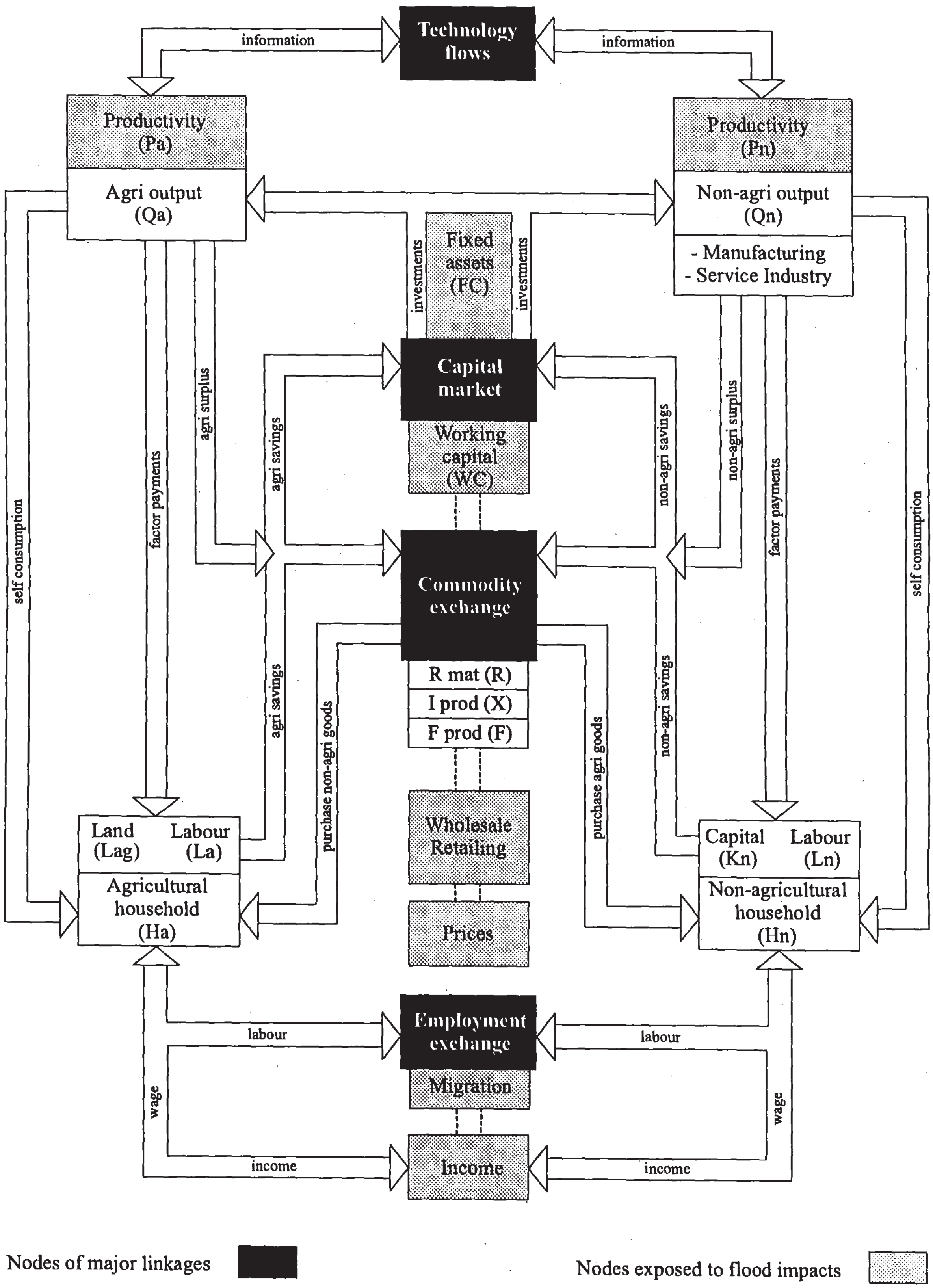
The first type of linkage in the form of 'technology flows' is a two-way interaction of information (via knowledge and education) between the two broad sectors, which eventually contributes productivity to each other. Nevertheless, this type of flow, rather a non-material type of linkage, is not directly or physically exposed to flood impacts.

Commodity and Capital Flows

The Commodity and Capital linkages briefly operate as follows. The flow of 'commodity' is a stock flow between the two sectors, in the form of raw materials (R), intermediate products (X), and final products (F), comprising capital and consumer goods. The commodities are distributed to consumers through retail and wholesale outlets. Prices act as a key determinant in adjusting the demand and supply of the commodity flows through these outlets. The 'capital' flows can be regarded as an outcome of the commodity flows, generated out of savings in the two broad sectors.

Figure 8.3 demonstrates the complex directions of the flows and interactions among commodities and capital outlay of the two major premises. As depicted in the figure, part of the total output in each of the two sectors is initially used as inputs in the same sector, and a part consumed by the producers themselves, with a part used as factor payments to land

Figure 8.3 : Link between inter-sectoral economic linkages and flood impacts



Source: Author, except adopted ideas of economic linkages from Ranis et al. (1990)

owners and labourers. The total surplus, which is thus the excess of production over consumption, proceeds to commodity market.

A part of this surplus is spent by the two sectors, on either commodity and equipment purchases or raw materials, with a part retained as savings flowing to the common capital market. Finally, the total savings from the two sectors make up the capital market of the whole economy, from which some moves, as investment, to each of the two sectors. A part of the investment takes the form of fixed capital investment, with a part comprising working capital, used for stock of inputs, output and factor payments.

A set of identities and equations can be formulated from the preceding relationships. In aggregate, savings in the agricultural sector are the agricultural surplus net of purchases from non-agricultural goods. Similarly, savings in the non-agricultural sector are the non-agricultural surplus net of purchases from the agricultural sector. The surplus of the two major sectors in the national economy is equivalent to total stock of commodities, R + X + F, where, R = total raw materials, X = intermediate products and F = final products. This amounts to national Gross Domestic Product (GDP).

Employment Flows

The two major production sectors, the agricultural and non-agricultural sectors, operate through the households in the respective territories via the common employment market. Depending on the demand and supply sides of the two sectors the perpetual labour movements flow in two directions until an inter-sectoral balance is sustained. In effect, with the exchange of employments, income flows also moves in the two directions.

In a developing country, where agriculture continues to be a major economic sector, the agricultural surplus plays a crucial role in the development of the non-agricultural sector, and the economy, as a whole. In a word, agricultural productivity generates demand on the non-agricultural sector, while growth in the latter raises demand for the output from the former. On the other hand, surplus in the two sectors is likely to be directly dependent on the level of the labour and output productivity. Thus the two broad sectors, agricultural and non-agricultural, are heavily inter-related.

8.6 Link between Economic Linkages and Flood Impacts

Within the linkages, the major 'Nodes' that are exposed to flooding are displayed in Figure 8.3. Out of the four major linkages, Commodity and Capital linkages are relatively more exposed to flooding. Direct damages include those affecting stock of commodities and assets and indirect impacts include those affecting 'flows' such as income, employment and prices. As shown in Figure 8.3, flooding is postulated to point to two major effects, one from the supply side and the other from the demand side. Productivity can be regarded as the key factor from the supply side, and income from the demand side. Having considered the two broad sectors, flooding in the agriculture sector normally first means a fall in output and land productivity, leading in turn to a fall in agricultural surplus. This results in adverse effects on savings and hence investment, which in turn contribute to adverse indirect impacts on wage and income of the households in the non-agricultural sector, and the agriculture sector itself. As a result of flooding in agriculture, the non-agricultural sector is likely to suffer from shortage of inputs and intermediate products.

From the demand side, the effects move in the other direction; with a fall in income in agricultural households demand for non-agricultural goods degenerates, leading to a fall in output and productivity in non-agricultural sector. This leads to widespread unemployment with subsequent adverse effects on wages, income and savings. On the other hand, with the fall in employment, both wages and incomes in agricultural households and production in the non-agricultural sector are likely to fall. Flooding in the non-agricultural sector affects the agriculture sector in a similar direction.

Figure 8.3 shows how all these linkages, in consequence, might have detrimental effects on the national Gross Domestic Product (GDP). Decline in income may eventually contribute to malnutrition, and shortage of production inevitably results in a price increase in food and other commodities. The adverse flood impacts, owing to inter-dependencies between the two sectors progress in a vicious and never-ending cycle. The analysis which follows seeks to test the validity of these postulations, with a special reference to productivity, output, value added and prices in the two sectors.

8.7 Macro-level Analysis

The discussion in the preceding section leads to several conclusions: (a) linkages in an economy are associated with innumerable dimensions and directions among various sectors (b) indirect impacts at the macro level are actually the net effects owing to decrease of products, on one hand, and increase of products owing to new investments on reconstruction and recovery activities, on the other, and (c) the linkage effects arise as the 'knock on' effect of primary indirect impacts, which further tend to result in chains of impacts, called multiplier effects.

Hence, flood impacts at the macro level are the spill-over effects net of all recovery activities, that are usually not confined within an individual, firm, locality or region, but spread beyond that. However, they are usually confined within the boundary of a national economy. Hence, the spill-over effects of flooding cannot adequately be confronted at micro level, and so linkage effects need to be addressed at the macro level. This analysis is an attempt to present some evidence of flood impacts at macro level which are actually the results of linkages that exist in the economy.

Analytical Framework

The methodology of analysis of flood impacts at the macro level involves estimating the trend using time series data over a reasonably long period. The trend or the growth curve is one of semi-logarithmic form (implying constant rate of change). The growth model is of the form, $Y = A' e^{BX} U'$ Or, $\text{Log } Y = A + BX + U$ which is linear in log Y and X, X being the independent (Time) variable and Y, the dependent variable (productivity, value added, price or as the case may be), and U being the stochastic factor, usually called disturbance factor (or residuals).

The trend estimated through fitting a Cobb-Douglas Production Function is of the form
$Q = A K^{\alpha} L^{\beta}$ where, Q = production
A = constant for technology, K = capital/fixed assets,
L = input for labour, and $\alpha + \beta$, the measure of return to scale.

These residuals or the deviations (from the estimated trend, either by semi-logarithmic form (through time) or Cobb-Douglas Function) form the basis of the present analysis. The residuals are analysed in relation to years of flood events.

An Alternative Approach of Analysing Fluctuations

Fluctuations in time series observations can be analysed in a number of ways. Coefficient of variation is often used as an index for measuring fluctuations. However, such a measurement is expected to overestimate the fluctuations if a statistically significant trend does exist in the series. It is thus first necessary to remove any trend element from the series before developing any measure of fluctuation. Cuddy and Valle (1978) have suggested an index for use in measuring fluctuations, if there exists any considerable trend element in the series. The index of fluctuation (FI) is as follows:

$$FI = CV\sqrt{1-R^2}$$

where CV = Coefficient of variation (Standard deviation/Mean), and R^2 = Coefficient of determination, adjusted for degrees of freedom.

The analysis uses this index as an alternative approach to examining fluctuations on incidence of diseases in relation to extent of flooding (See Islam 1997a).

Data Sources and Data Limitations

The following major sources are used for the data employed in the analysis:

a) Statistical Year Book, Yearly Series, various issues, Bangladesh Bureau of Statistics; 20 Years of National Accounting of Bangladesh: Data on industrial and agricultural GDP, production figures on selected large industries.

b) The Bangladesh Census Manufacturing Industries, Yearly Series, Bangladesh Bureau of Statistics: Data on output, gross value added, employment, fixed assets etc in small and medium-sized industries.

c) Economic Trend, Monthly Series, Bangladesh Bank: Data on productions on selected large industries.

d) Daily Newspapers (The Bangladesh Observer): Data on number of hours of work strike.

e) Power Development Board, Bangladesh: Data on power disruption (load shedding).

The macro level analysis is thus largely based on official statistics, available in published documents such as Statistical Year Books, Census of Manufacturing Industries and District Series of Population Census. It is important to raise a few points on the sources and quality of data used in the analysis.

Bangladesh Bureau of Statistics is a centrally-managed data collecting agency under a separate Division of the Ministry of Planning, Government of Bangladesh. It publishes voluminous data annually in the form of Statistical Year Books and other documents. The basic job of the data collection is carried out by Thana Statistical Offices, which compile reported information from Union Parishads and villages. The Thana information is then collated at the District and ultimately, at national level. Population figures including statistics on urbanisation are estimated by the Census of Population, conducted every after ten years.

Statistics on urbanisation appear to be erroneous and inconsistent. The definitions of urban areas adopted in different censuses are inconsistent. For example, the 1981 Population Census considered a concentration of population of at least 5,000 persons in continuous collection of houses, where community sense had developed and where there was either Municipality (Pourasava) or Town Committee or Cantonment Board. The census included all the 460 upazila (formerly, Thana) headquarters (irrespective of the size of population), and all Hats and Bazars with electricity as urban areas. The 1991 Census excluded the 460 upazila headquarters from being urban localities. The Census defined, in all, the 125 Pourasava (municipalities) to be the urban areas. Thus, due to definitional problems, urbanisation statistics over different times (particularly with the 1991 figures) are not often comparable. Besides, in estimating urbanisation growths over time, rates of out-migration are not taken into account. A comparison of urban population over the last two censuses (1981 and 1991) demonstrates that the population in several important towns have shown a decline, which is not feasible. Hence, so far as the data published in Statistical Year Books, urban population figures (for 1991 Census) are erroneous and need to be used with caution[112].

Nevertheless, the published data are widely used by national and international agencies for the planning and research purpose. The other demographic and population estimates carried out by the Population Census, which are widely used by organisations such as World Bank,

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[112] This view is supported by ADB (1994).

UNDP and WHO, can be taken as reasonably reliable. The BBS conducts Census of Manufacturing Industries (CMI) every year and routinely collect industrial data from entrepreneurs through largely mail questionnaire methods. It covers all industrial units subject to Factories Act (1934) and included under Bangladesh Standard Industrial Classification (BSIC) at four digit levels. The data on CMI are also widely used in research purposes and the quality of data are not seriously questioned.

The methodology adopted by BBS in the agricultural damage data collection have often been questioned (Montgomery 1985; Thompson 1989; BIDS researchers e.g. Hossain 1990). The Thana authorities compile reported damage either from their own observations or reports from Union Parishads. Information is collected at the time of floods or in the immediate aftermath, so that the access to remote and badly affected areas are frequently demanding. Hence, the assessment of agricultural losses is subject to bias in the face of particularly resource and time constraint, as the data are often urgently required. Montgomery (1985) found little relationships between deviations from trend and official loss statistics on Boro and Aus, the two rice crops. Hossain (1990) carried out a trend analysis and found that degree of instability is higher for normal production, demonstrating the weakness of the official statistics of losses from natural disasters. Nevertheless, the present analysis (as will the be seen in subsequent sections) found a strong relationships between deviations from trends of official estimates of production and flood affected areas for Aman, the main wet season rice crop. This demonstrates no strong evidence that the official crop loss data, at least for Aman crop, are highly inconsistent.

Findings of Macro-level Analysis

8.8 Fluctuations on Agricultural Production

8.8.1 Crop Damage and Natural Hazard

The analysis first requires that fluctuations of agricultural production at national level owing to flooding are considered, as in the subsequent sections the fluctuations of other sectors of the economy are analysed in relation to agricultural fluctuations. At the outset, an aggregate account of damages to major crops over years and regions due to natural hazards (with particular reference to floods) is important. Crop damage information is compiled for the period 1962 through to 1991. Since crop production dominates agriculture, and rice production dominates crop production, rice crops are the major concern of the analysis[113]. Among rice crops, the wet season rice, Aus and Aman, and the dry season rice, Boro, are included in the analysis. In addition, two major cash crops, jute and sugar cane are considered.

Table 8.1 shows the reported crop damages by natural hazards over a 30 year period, 1962-91[114]. In an average year, rice crops together are damaged in the range of 3.5% due to floods, and about 0.6% due to cyclones of the total potential production[115]. In other words, floods are the source of major damages, accounting for 85% of the total damages to rice crops caused by natural hazards. Cyclones account for the remaining 15% of the total damages. Of the Aus crop damage, floods are the source of damage by 96%, with the remaining 4% attributable to cyclones. For Aman crop, damage attributable to floods is 85%. For Boro, however, the damage attributable to floods is 53%, with the remaining 47% attributable to cyclones. Hence, in respect of individual crop damage by the two natural hazards, Aus is more susceptible to floods than cyclones.

In terms of absolute damage, however, among the wet season rice crops, Aman rice suffers the maximum flood damage, amounting to 315,000 tonnes in an average year, which constitutes more than 4.1% of its potential production. The reported flood damage to Aus crop is about 137,000 tonnes annually, which accounts for about 4.6% of its total potential production. The cash crops, jute and sugar cane suffer damages to the extent of about 2% and 1% of the total potential production respectively.

Almost all the districts in Bangladesh are affected by the annual phenomenon of floods, though the intensity of flooding and extent of damages vary considerably from region to region and from year to year (Table A8.1, Appendix Section). From the regional point of view, it appears that the Eastern region is more susceptible to crop damages, both for Aus and Aman. The average damage of Aus accounts for approximately 8% of the potential

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[113] Crop productions constitute 78% of the total value added in agriculture, and cereals constitute 75% of the total value added in crop production. Among the cereals, rice crops are the major ones, comprising approximately 90% of the value added (BBS 1993).

[114] Natural hazards here include floods and cyclones, as data on the other type of natural hazard, drought, are not available.

[115] Potential production refers to actual production plus damages estimated.

Table 8.1 : Crop damage by natural hazards during 1962-1991

(Damage value in 000 M tonens)

Crop	Total damage due to		Total potential production
	Flood	Cyclone	
<u>Wet season rice</u>			
Aus	4111	152	88864
	(4.6)	(0.2)	
Annual mean	137.0	5.1	
CV	1.2	3.0	
Aman	9439	1639	232431
	(4.1)	(0.7)	
Annual mean	314.9	54.7	
CV	1.4	2.8	
<u>Dry season rice</u>			
Boro	814	704	90103
	(0.9)	(0.8)	
Annual mean	27.2	23.5	
CV	2.7	3.4	
<u>All rice crops</u>			
Aus+Aman+Boro	14374	2496	406508
	(3.5)	(0.6)	
Annual mean	479.1	83.2	
CV	1.2	2.1	
Jute	656	69	31075
	(2.1)	(0.2)	
Annual mean	21.9	8.6	
CV	1.2	1.0	
Sugarcane	2200	214	207018
	(1.1)	0.1)	
Annual mean	73.3	7.1	
CV	2.1	2.5	

Note:
: Potential production denotes actual production added with flood loss; figures in parenthesis represent loss percentages to potential production;
: CV, Coefficient of variation over years = St deviation/mean;
: Compiled from yealy issues of BBS-Statistical Year Book and Agricultural Production Levels.

production in this region, as against in the range of 3 to 4% in the other three regions. In terms of Aman crop, however, the Central region seems to be more susceptible, damages approximately accounting for 6% of the production, as against in the range of 3 to 4% in other regions. The estimates of coefficient of variations (CVs) indicate that generally the districts are more or less uniformly flood prone in so far as damages to Aus and Boro are concerned. So far as Aman is concerned, The Eastern (CV=1.21) and South West regions (CV=.83) are more susceptible, compared to the other two regions (CV=.41 and .43 for North West and Central region respectively).

The extent of damages appears to vary significantly over years during the period, 1962-91. This is reflected in the estimates of CVs over years. As can be evidenced from the Table 8.1, the estimated coefficients appear to be quite high, far exceeding unity in all the cases, both for flood years and cyclone years. However, the coefficients appear to be even higher in the case of cyclone years, exceeding two, and even three in some cases.

8.8.2 Trend Estimates

The estimated semi-log trend lines for major food and other crops, both in terms of acreage and output, over a period 1962-92[116] are presented in Table 8.2. In terms of acreage, the acreage under wet season rice crops (Aus + Aman) and jute has shown a decline at a rate of 0.2% and 1.2% respectively, while that under the dry season rice crop, Boro, has shown an increase of about 6%. Trend estimates in output, however, show that both wet season and dry season rice crops have increased, at a rate of 0.8% and 7.9% respectively.

It is evidenced that there are considerable variations in the production of agricultural crops, which is indicated by respective standard errors. However, the production variations are more pronounced in the case of Boro among the rice crops, and jute among other crops.

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[116] A 31 year period is selected for the analysis, although during this period there was a shift of rice production technology in the early 1970s. Following that a number of major floods occurred in the 1960s the research includes this period in the analysis. See Hossain (1990), who has analysed instability in food grain production in Bangladesh over a period 1973-90.

Table 8.2: Semi-log trend equations for crop acreage and production

Crops	Inter cept	Trend rate of growth	Standard error	R^2	F. signif. level	D-W Statistics	N
TREND FOR AREA							
Aus	8.97	.006	.0027	.15	.04	.30	31
Aman	9.58	-7.44E-04	8.16E-04	.03	.37	1.32	31
Aus+Aman	10.01	-.002	.0011	.14	.04	.60	31
Boro	7.00	.058	.0031	.93	.00	.58	31
Jute	7.65	-.012	.0040	.25	.00	1.12	31
Sugar	5.85	.007	.0017	.40	.00	.68	31
TREND FOR OUTPUT							
Aus	7.93	8.69E-04	.0026	.004	.74	.79	31
Aman	8.73	.011	.0022	.47	.00	1.43	31
Aus + Aman	9.10	.008	.0018	.44	.00	1.51	31
Boro	6.47	.079	.0052	.89	.00	.40	31
Jute	7.00	-.006	.0041	.07	.15	1.44	31
Sugar	8.76	.004	.0025	.10	.09	.69	31

Reference period = 1962/63-1992/93

8.8.3 Annual Fluctuations on Agricultural Production

The deviations of the actual production from the estimated semi-logarithmic trend lines for various crops for the period 1962-92 are estimated[117]. The absolute deviations are presented in Table 8.3 and per cent deviations are presented in Table A8.2 (Appendix Section). As is evident from Table 8.3, during the period of 31 years, the production of wet season rice crops (Aus and Aman) had fallen below the trend in six out of nine severe[118] flood years. The total shortfalls in these six flood years are estimated at 5.7 million tonnes. Taking into account the positive deviations in three flood years, the total net shortfalls above the normal trend production during these nine severe flood years stands at 3.9 million tonnes. So far as the dry season rice crop (Boro) is concerned, during these nine severe floods the production had fallen below normal output in three years, estimating the shortfall at 0.75 million tonnes in this period. Despite this shortfall in three years, the net additional production in Bor*o* during these nine severely flood affected years is estimated at 2.6 million tonnes above the normal production.

From Table A8.2 it is evident that in the recent disastrous flood of 1988 (a flood with an approximately 60 year return period), Aman production has fallen short by 18% below the normal trend production. The shortfall in wet season rice crops together (Aus + Aman) is 13% below the trend production. The production of the dry season rice crop (Boro), however, is 7% above the normal trend. This implies that the shortfalls in the wet season, especially in Aman production, are to a large extent offset by dry season crop in the same year/season[119].

The production of jute in nine flood years has shown a net shortfall of about 0.4 million tonnes below the normal trend production, while sugar cane records a net shortfall of about 0.7 million tonnes over the same period. In 1988, for example, the production of jute and

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[117] Since R^2 for Aus has shown statistically insignificant, the deviations of the two wet season crops combined (Aus + Aman) are contemplated.

[118] Severe floods in this analysis are defined as those floods affecting more than one quarter of the country; nine such floods have occurred in the last three decades. The years are 1962, 1963, 1968, 1969, 1970, 1971, 1974, 1987 and 1988. See Table 8.15.

[119] For a similar finding, see, for example, Asaduzzaman (1994), Hossain (1990), Shahabuddin (1989) and Murshid (1987) .

Table 8.3: Absolute deviation from semi-log trend for agricultural crop production

(IN 000 TONNES)

	RICE CROPS				OTHER CROPS	
	WET SEASON			DRY SEASON		
YEAR	AUS	AMAN	TOTAL	BORO	JUTE	SUG CANE
1962/63	-611	-46	-607	-215	54	-1540
1963/64	-146	1145	1043	-245	-17	-945
1964/65	-302	1045	779	-244	-109	-92
1965/66	125	500	654	-264	145	1220
1966/67	-120	-469	-566	-120	98	1719
1967/68	285	363	663	89	154	1201
1968/69	-104	345	250	509	-6	875
1969/70	183	349	535	713	257	968
1970/71	85	-784	-702	906	173	1121
1971/72	-443	-1083	-1535	337	-271	-851
1972/73	-509	-1273	-1796	558	157	-1255
1973/74	32	-224	-212	584	70	-244
1974/75	93	-1016	-949	478	-382	23
1975/76	473	-38	405	367	-292	-768
1976/77	253	-263	-44	-439	-128	-275
1977/78	350	176	488	-14	-22	-32
1978/79	541	98	596	-516	180	97
1979/80	57	-117	-106	-212	99	-429
1980/81	495	1860	2306	-266	-80	-303
1981/82	479	-506	-80	19	-127	203
1982/83	278	-201	20	157	-79	394
1983/84	437	41	419	-316	-13	173
1984/85	2	-57	-116	-57	-26	-149
1985/86	94	458	488	-619	624	-419
1986/87	353	92	380	-630	283	-195
1987/88	221	-581	-427	-288	-83	84
1988/89	87	-1510	-1491	402	-125	-448
1989/90	-278	737	391	294	-83	236
1990/91	-435	604	99	4	43	462
1991/92	-581	606	-45	-68	-9	194
1992/93	-682	916	164	-846	NA	222

Note :
Figures are rounded off to next decimal places or integers.

sugar canes fell below the normal trend production by 13% and 6% respectively (Table A8.2).

8.8.4 Link between Floods and Crop Damage

In order to examine the link between flooding and damage to agricultural production an hypothesis correlating the deviations from trend with corresponding total flood-affected areas is formulated as follows: the larger the areas affected by floods, the greater will be the negative deviations expected below the estimated (normal) trend; that is, a negative correlation is expected of the deviations with flood affected areas.

Table 8.4 shows simple correlations and rank correlations, of deviations (from the estimated trend) for agricultural crops with flood affected areas over the period of investigation. There seems to be no evidence against the hypothesis for the wet season crops. It is evident that both for Aman individually and wet season (Aus + Aman) crops together, the correlations are negative, as expected, and also statistically significant at accepted levels of significance[120]. For the dry season crop (ie Boro), however, the correlation is found to be positive and highly significant (at 3% level).

This suggests, again, that the shortfalls in wet season rice crops are largely compensated by increased production in the dry season rice crop in the same year (See crop calendar in Figure 8.4). In other words, the farmers put additional efforts into the production of the dry season crop (Boro), in recovering losses of the wet season crops. Replanting of the Aman crop after the flood damage is also frequently helpful in compensating the seasonal losses. The recovery process is likely to be facilitated by increased provision of irrigation and modern inputs, such as modern seeds and chemical fertilizers through credit and other extension services. The efforts might also include employment of additional labours, as there is huge disguised un- and under-employment in the agriculture sector (Clay and Khan 1977; Clay 1987). An additional factor responsible for the positive correlation might support the conventional notion that flooding often increases the productivity of land through increase in soil fertility, Boro land in this case[121]. Besides, shortfalls in affected regions are to a large

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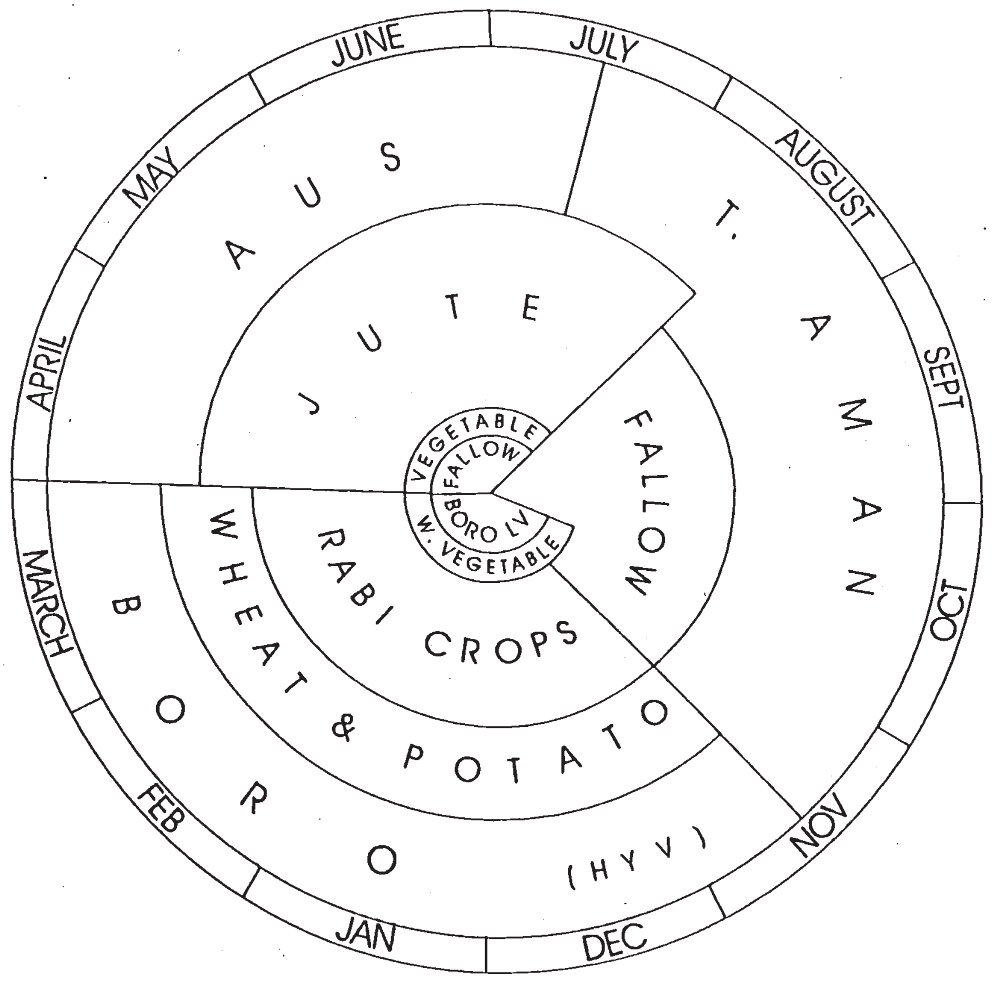
[120] 5% level is considered as the accepted level of significance in this analysis.

[121] This is not just a traditional notion, some flood researchers have supported this. See e.g. Prasad (1981); Paul (1984); Hossain (1990); Brammer (1990a) and Asaduzzaman (1994).

Table 8.4: Correlation of deviations from trend with flood affected areas

	Correlation			Rank correlation		
	Pearson's coefficient	Signif. level	N	Pearson's coefficient	Signif. level	N
<u>WET SEASON</u>						
Aus	.04	82	31	-.17	36	31
Aman	-.39	3	31	-.29	11	31
Aus + Aman	-.36	5	31	-.28	13	31
Jute	-.27	14	31	-.20	27	31
<u>DRY SEASON</u>						
Boro	.39	3	31	.36	4	31
Sugar cane	-.05	80	31	-.14	45	31

Figure 8.4 : Approximate crop calendar



This crop calendar applies to IRRIGATED land.
For RAINFED cultivation, the land under Boro rice crop is usually kept fallow.

extent compensated by above normal production in non-affected regions during the same season[122]. An expectation of rising prices in the face of shortfalls might induce farmers in mobilising all possible resources (including savings) towards an increased production above the normal level.

The estimates of correlation for jute (Table 8.4) show that floods adversely affect the production of jute, but this is only significant at 14% level. The reason that damage to jute is not firmly evidenced might be that the crop can to some extent withstand flood water before damages are started. As regards sugar cane, although the sign of the coefficient is negative, as expected, the coefficient is not significant at any acceptable level.

8.9 Impacts on Industries

The investigations are carried out on three groups of selected industries: a) small and medium-sized industries b) large industries and c) industries having differential linkages with the agriculture sector. Finally, the industries sector, as a whole, is examined. Trend estimates are carried out both on semi-logarithmic models and the Cobb-Douglas production models, on both gross output and value added.

8.9.1 Small and Medium-sized Industries

The analysis is carried out to examine the productivity of the small and medium-sized industries, the units selected from the Census of Manufacturing Industries. Productivity is defined as the gross output or value added per employed person. Appendix Tables A8.3 and A8.4 present the estimated semi-logarithmic trend and Cobb-Douglas function respectively. It is evident that both the form of trend equations on time series data fit well at more than 95% level.

Absolute and per cent deviations from trends are presented in Tables A8.5 through to A8.8 (Appendix Section). Table 8.5, compiled from these Appendix Tables, furnishes a summary of per cent deviations in three selected severe flood years, the deviations taken from both semi-logarithmic and Cobb-Douglas function. However, the former (semi-logarithmic) form

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[122] This is concluded by Hossain (1990) in analysing trends in food grain production at regional levels.

Table 8.5: Percentage deviations from trend of selected CMI-small and medium-sized industries in selected flood years

Semi-logarithmic trend

Industries	% Deviations on productivity (Annual output/employment)			% Deviations on value added (Annual value added/employment)		
	1984	1987	1988	1984	1987	1988
Rice mill	-12	-14	-18	-24	16	-33
Handloom	-29	17	-2	-15	13	4
Saw mill	-40	13	-32	-18	21	-48
Furniture	13	14	-64	-10	20	-60
Glass	1	-18	1	9	-8	5
Motor vehicles	36	8	-25	35	-17	-38

Cobb-Douglas production function

	(Annual output)			(Annual value added)		
Rice mill	16	43	-25	-14	27	2
Handloom	-22	25	-9	-11	8	2
Saw mill	-34	7	-7	-13	6	-7
Furniture	-24	27	-46	-28	35	-48
Glass	26	20	-4	41	34	-7
Motor repair	58	73	-28	48	24	-33

Note :
Compiled from Tables A8.5 through to A8.8 (Appendix Section).

of equation appears to be more suitable for examining trend. Because, the latter (Cobb-Douglas function) form of trend, based on the data on fixed assets and employment, has the likelihood of being underestimated as fixed assets themselves in relevant flood years are subject to damages.

Table 8.5 indicates that the flood of 1988 has impacted more adversely than the other two floods on productivity. Of the type of industries, furniture and saw mills appear to be more severely affected in both 1984 and 1988 floods. For example, in the 1988 flood the productivity (on value added) of the furniture and saw milling industry declined by 60% and 48% respectively. The flood of 1987, however, appears to have a minimum adverse impact on the productivity of selected small and medium industries.

Likewise, it is postulated that the negative fluctuations will be associated with the larger floods having relatively large affected areas. The correlations of deviations (from trend) with flood affected years are presented in Tables 8.6 and 8.7. The most striking feature is that flooding has adverse impacts on all the selected small and medium-sized industries, indicated by negative correlations. This is evident for both the form of trend estimated, semi-logarithmic and Cobb-Douglas function. Nevertheless, the industries, rice milling, saw milling and furniture appear to be the more severely affected units and the hand looms are the least affected ones. However, the statistically valid negative relationship is found only for furniture units.

8.9.2 Selected Large Industries

Table 8.8 presents estimated trend equations on time series data for 14 selected large industries[123], which shows that R^2 for all except oil, cigarette and power pump industries are highly significant. The cloth industry is the only one with negative growth (of about 1.6%). The other industries have a positive rate of growth ranging from 1.9% for yarn to as high as 12.5% for urea fertilizer.

Likewise, the hypothesis of negative correlations, of the fluctuations (from trend) with flood affected areas is tested. Table 8.9 presents simple and rank correlations. Setting aside those industries showing no statistically significant trend (e.g. oil, cigarette and power pump),

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[123] The selection of the industries depended heavily on the data availability.

Table 8.6: Correlation of deviations from trend with flood affected areas

CMI-Industry	Pearson's corr. coeff.	Signif. level	N	Rank corr. coeff.	Signif. level
Semi-logarithmic trend (Productivity:G output/Employment)					
Rice milling	-.39	.27	10	-.44	.20
Handloom	-.05	.89	10	.04	.92
Saw milling	-.35	.32	10	-.19	.59
Furniture	-.75	.01	10	-.60	.07
Glass	-.24	.50	10	-.04	.92
Motor repair	-.13	.72	10	-.08	.82
Semi-logarithmic trend (Productivity:G value added/Employment)					
Rice milling	-.50	.14	10	-.53	.11
Handloom	.01	.99	10	-.04	.92
Saw milling	-.35	.32	10	-.13	.72
Furniture	-.66	.04	10	-.52	.12
Glass	-.10	.79	10	.07	.85
Motor repair	-.29	.41	10	-.09	.80

Note:

N = No of observations.
Reference year 1979/80 - 1988/89
Compiled from Tables A8.5 through to A8.8 (Appendix Section).

Table 8.7: Correlation of deviations from trend with flood affected areas

Cobb-Douglas function (Gross output)

CMI-Industry	Pearson's corr. coeff.	Signif. level	N	Rank corr. coeff.	Signif. level
Rice milling	.33	.36	10	.60	.07
Handloom	-.02	.96	10	.08	.83
Saw milling	-.25	.49	10	-.40	.26
Furniture	-.51	.13	10	-.60	.07
Glass	-.23	.53	10	-.26	.47
Motor repair	-.05	.89	10	.01	.99
Cobb-Douglas function (Gross value added)					
Rice milling	.30	.40	10	.24	.51
Handloom	.09	.81	10	-.31	.39
Saw milling	-.21	.56	10	-.27	.45
Furniture	-.46	.18	10	-.52	.12
Glass	-.01	.98	10	-.18	.63
Motor repair	-.22	.54	10	-.06	.87

Note:

N = No of observations.
Reference year 1979/80 - 1988/89
Compiled from Tables A8.5 through to A8.8 (Appendix Section).

Table 8.8: Semi-log trend estimates for selected large industries

Industries	Inter cept	Trend coeffi cient	Standard error of estimate	R^2	F signi. level	D-W statis tics	No of case (N)
Cloth	11.44	-.016	.0039	.49	.00	1.03	20
Paper	9.64	.036	.0054	.71	.00	1.62	20
Oil	9.60	.010	.0161	.02	.53	1.35	20
Food	9.70	.035	.0149	.23	.03	.56	20
Sugar	11.19	.031	.0116	.28	.02	1.49	20
Glass	5.66	.052	.0057	.82	.00	2.00	20
Iron-steel	13.77	.072	.0205	.41	.00	.68	20
Cigarette	11.29	.021	.0240	.04	.38	2.03	20
Chemical	7.22	.070	.0071	.84	.00	.67	20
Urea	10.51	.125	.0110	.87	.00	2.20	21
Match	8.41	.039	.0062	.69	.00	.37	20
Newsprint	9.59	.044	.0089	.58	.00	1.31	20
Yarn	5.14	.019	.0024	.77	.00	.95	20
Power pump	7.21	.078	.0416	.18	.08	1.26	20

Note:
Reference period = 1973/74-1992/93 for all industries other than Urea.
Reference period for Urea = 1972/73-1992/93.
Urea production excludes that for the largest factory, namely Jamuna Fertilizer,
which went to production in 1991-92. This production is excluded in order to get the general trend undistorted.

Table 8.9: Correlation of deviations from trend with flood affected areas

Industry	Pearson's corr. coeff.	Signif level	N	Rank corr	Signif level
Cloth	.11	67	20	.16	53
Paper	.17	51	20	.14	58
Oil*	.00	99	20	-.04	86
Food	.39	11	20	.34	17
Sugar	-.41	9	20	-.30	22
Glass	-.22	37	20	-.36	14
Iron	-.10	69	20	-.08	75
Cigarette*	.26	30	20	-.05	83
Chemical	.07	79	20	.07	78
Urea	.52	3	21	.27	28
Match	.02	95	20	.16	52
Newsprint	-.07	79	20	.01	98
Yarn	-.02	93	20	.00	99
Powerpump*	.28	27	20	.06	80

Note: N = No of observations.

* Trends estimated in Table 8.8 are not statistically significant

sugar, glass, iron, newsprint and yarn show expected negative correlations, but only for the sugar industries is the correlation found to be significant at a 9% level (Table 8.9). Hence, there is little evidence that the production in selected large industries is significantly affected by the extent of floods. In addition, the estimates of rank correlations do not suggest any changes to the above conclusion.

There are several explanations. One could be that the recovery activities in the industries sector have been strong and fast, in consequence of which the net effects at the end of the year are trivial. It can be argued that the wide-scale, idle-capacity situation prevailing in the sector might have subsequently pushed the enterprises to compensate the losses caused by floods to a great extent. It is also possible that the factors such as external economies, demand-supply and profit motivations have induced particularly the non-flooded enterprises to augment their output following the production losses incurred by the flooded units. In effect, the annual production at the national level appears to have been least affected. It can also be argued that the recovery activities which include immediate measures including government and non-government measures, on the one hand, and international responses, on the other, have been strong enough to have dampened the adverse impacts, especially in the event of larger floods[124].

8.9.3 Industries Linked with Agriculture

The effects of agricultural flooding[125] on industries are examined by analysing the deviations from the trend for the group of industries having linkages with agriculture to a varied extent[126]. The group of industries analysed in the previous section include units having a) relatively higher backward linkage (e.g. food and sugar), and b) higher forward linkage (e.g. fertilizer and power pump)[127].

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[124] The amount of foreign economic assistance (including food aid) has a trend of increasing in larger floods. See Section 8.10 and Footnote 131.

[125] It is assumed that total flood affected areas adequately represent flooding in agriculture.

[126] Agriculture represents only agricultural cropping, which dominates the agriculture sector in Bangladesh.

[127] Backward linkage refers to one if the production activity of one sector requires inputs from the other, and the forward linkage is the one if one sector supplies output to another sector.

The correlations of the deviations from output trend with the extent of affected areas are expected to be significantly negative in these two groups of industries. The results show no such significant negative relationships, except for sugar which is significant at 9% level (Table 8.9). Nevertheless, this does not necessarily imply that flooding of agriculture has no effect on industries. It is possible that the shortfalls in input from and output to agriculture are compensated by the stock from the previous years. Again, the lag-year correlations (not presented here) also appear to have not generally changed the finding. What follows is that so far as the selected large industries are concerned, there is not enough evidence that agricultural flooding substantially affects the industrial production. In fact, the urea production shows a significant positive relationship with flood affected areas. This can possibly explained in that the production of urea might have increased due to enhanced demand, as argued before, derived from the farmers during the flood years, particularly in the Boro season.

It needs to mention that the above analysis of production fluctuations of industries, based on the national data, could be improved if use could be made of any separate data on the extent of urban and agricultural flooding, which are not available. In the absence of such information on the extent of flooding by type of industries firm conclusions are difficult to derive.

8.10 Sectors at Aggregate Level

The national level analysis carried out on major sectors of the economy demonstrates that the deviations (from trend on value added) in small, large and all industries (combined) sectors are strongly related to deviations in value added in the agriculture sector, which is true for simple and rank correlations, and both at current and constant prices (Table 8.10). Despite these strong linkages in the economy, the deviations from the trend on agriculture, industries and national GDP are found to be least related to flood affected areas, at current or constant prices (Table 8.11). While the sign of the correlation coefficient with industries sector has shown negative, as expected (however, not significant), the signs of the coefficient with neither the agriculture sector nor the national GDP are found to be negative.

Table 8.12 presents per cent deviations of value added from the trend of major sectors of economy at constant 1984-85 prices, which depicts that for agriculture, adverse (negative)

Table 8.10: Linkage between industries and agricultural sector

Sectors	Correlation of deviations (from Trend) (at current price)				
	Pearson's corr.	Signif. level	Rank corr.	Signif. level	N
Small Industries with Agriculture	.74	.00	.55	00	19
Large Industries with Agriculture	.65	.00	.39	9	19
All Industries with Agriculture	.69	.00	.49	3	19

Sectors	Correlation of Deviation (from Trend) (at constant 84-85 price)				
	Pearson's	Signif. level	Rank	Signif. level	N
Small Industries with Agriculture	.86	00	.61	00	19
Large Industries with Agriculture	.38	11	.37	11	19
All Industries with Agriculture	.65	00	.56	1	19

Note : Deviations are taken from semi-log trend on value added (Table A8.9).

Table 8.11: Correlation of deviation (from trend) with flood affected areas for major sectors

Sectors	At Current Price		At Constant (1984-85) Price		
	r	Sig level	N	r	Sig level
Agriculture	.08	.74	19	.21	.39
Industry	-.26	.28	19	-.13	.59
National GDP	.05	.83	19	.10	.69

Note : Deviations are taken from semi-log trend on value added (Table A8.9).

r = Pearson's correlation
N = No of observations

Table 8.12: Per cent deviations from trend on major sectors of the economy

Year	% Deviation from trend of value added (at constant 84-85 price)			
	Small industry	Large industry	All industry	Agriculture
1972/73	-.12	-38	-17	-3
1973/74	.06	12	4	5
1974/75	.00	-24	-12	-3
1975/76	.09	-9	-6	3
1976/77	.02	16	6	-3
1977/78	.04	15	6	3
1978/79	.06	32	14	-1
1979/80	-.04	29	13	-3
1980/81	.07	14	6	.3
1981/82	-.03	1	-1	-1
1982/83	-.08	7	3	1
1983/84	-.14	14	7	2
1984/85	-.06	.32	-.28	.8
1985/86	-.01	-4	-2	3
1986/87	.01	1	1	.1
1987/88	.04	-6	-3	-3
1988/89	.05	-11	-5	-5
1989/90	.02	-9	-3	2
1990/91	.02	-14	-6	2

fluctuations from the trend in 1987 and 1988 (the most catastrophic floods on record[128]) are in the range of 3 and 5 per cent respectively. For large industries, the negative impacts are relatively high, in the range of 6 and 11 per cent below the trend in the two floods respectively. For small industries, however, the deviations (from trend on value added) in these two years are not found to be negative[129]. For industries sector (small and large combined), as a whole, it is revealed that adverse (negative) fluctuations from the trend in 1987 and 1988 are in the range of 3 and 5 per cent respectively. The deviations at current prices are shown in Appendix Table A8.10.

8.11 Impact on Prices

Table A8.11 (Appendix Section) demonstrates trend estimates for semi-logarithmic equations on prices, illustrating that all the equations fit extremely well. Table 8.13 presents the price fluctuations (from trends on price/Quintile) of rice, food and manufacturing (trends on price index, 1970=100) in four severe flood years. It can be observed that the maximum price hikes in rice (71% above the normal trend) occurred in 1974 and the minimum occurred (0.2%) in 1988. It can be mentioned that a famine occurred immediately in the aftermath of the 1974 flood[130]. One can also mention in this regard that the amount of foreign economic assistance (including food aid) in the previous year (i.e. 1973-74) had fallen by 38% (below normal trend), while it had generally increased during the time around 1987 and 1988 flood. For example, the per cent increases (above normal trend in aid) were 11%, 8% and 3% in the year 1986/87, 1987/88 and 1988/89 respectively[131].

Thus, the prices in 1988, the year of the most disastrous flood in the history, were more or less stable so far as the trend estimates are concerned. The deviations of rice prices (from

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[128] The 1987 and 1988 floods inundated 40% and 63% of the country's total area respectively (See Table 8.15).

[129] About 82 % employment and 43 % value added in the total manufacturing sector originates from small and cottage industries sector (The Fourth Five Year Plan, 1990-95, Planning Commission)

[130] The 1974 famine claimed several hundred thousand people. Sen (1981) categorically found that, even with no significant fall in per capita food availability, 'lack of entitlement to food' with sudden price hikes was the main reason for the starvation. Similar finding was also reached by Islam (1974).

[131] The semi-log trend equation estimated (1973/74 - 1992/93) is $\text{Log (AID)} = -107.6017 + .0578\ (\text{YEAR})$ (adjusted $R^2=.76$; $N = 20$; D-W Statistic = 1.49).

Table 8.13: Fluctuation in commodity price in selected flood Years

	Absolute deviation from trend				% deviation from trend			
	Major flood years				Major flood years			
Price item	74	84	87	88	74	84	87	88
Rice price	253	116	105	2	70.5	14.4	10.2	0.2
All food price	125	42	41	15	42.1	5.5	4.0	1.3
Manufact price	107	25	-41	-67	29.7	3.2	-4.2	-6.5
Flood affected areas (000 km)	53	28	57	90	53	28	57	90

Note:

Analysis is carried out for rice: on wholesale price (TK/Quintile);
for other items: on price indices (1970=100).
Reference period = 1972-91

trend) over the four years of severe floods appear to have a tendency to fall with the increase in affected areas. This can possibly be explained in that stronger measures were adopted in larger floods, on the part of, possibly, both government machinery and non-government organisations, to keep the prices under control. Import of food grains during floods is often a political measure, rather than an economic measure[132]. In these type of catastrophic situations, the prices are usually controlled through considerable import of food grains often on an emergency basis. Besides, response by the international community in the form of relief, grants and aids might have also helped dampen the prices.

Indeed, the manufacturing prices have the tendency to show a negative relationship with flood affected areas. This again may be attributed to similar measures adopted, on the one hand, and decline in demand generally for industrial products, on the other[133].

8.12 Multivariate Analysis

From the preceding analysis, there are reasons to believe that the fluctuations in industrial production are due to factors other than flooding. In order to pursue this, a multivariate analysis is carried out incorporating other intervening variables that are likely to influence the dependent variable - the industrial production. The analysis is carried out on the 14 large industries previously selected.

The investigation first requires flood proneness (FLOOD) to be considered as an independent variable; it may be reasonable to regard the total flood affected areas of the country over different years as proxy to flood proneness[134]. Besides Flood Proneness, fluctuations in industrial production are likely to be influenced by many other variables; one important

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[132] Hossain (1990) argues that imports of food grains 'put a downward pressure on market prices', and the 'years of natural calamities have experienced large increases in food grains imports and off-takes from government held stocks through Public Food Distribution System (PFDS)'

[133] The overall decline in demand for industrial products in the main case study area (Tangail town) in the aftermath of 1988 flood year, for example, is estimated as 34%.

[134] The flood affected areas over years are collected from Hydrology Department of BWDB; the figure for 1979 and 1981 are not available, which are estimated by regressing Aman crop damage on flood affected areas over years (R^2 = .69).

variable might be the fluctuations in agricultural production[135].

It is often said that 'urbanisation is concomitant of industrialisation' (Ranis et al 1990). Thus, it is considered that the level of industrial production is related to size of urban population. More precisely, the variable, Urbanisation Index (URBIDX) is included as an independent variable, which is defined as the share of urban population to total population in relevant years in the country. Although per capita income has shown a little variations over the first decade of the present reference period (1970s) there has been some variations in the recent years; so per capita income (INCOME) is considered as another explanatory variable[136].

There can be other exogenous variables, such as work strike due to political instability[137], which can substantially influence the dependent variable. Hence, political instability (POLINS) is regarded as an intervening variable in the analysis. The number of hours of work strike (*hartal*) over years[138] is considered as a proxy to Political Instability (POLINS).

Another variable in relation to Power supply can be considered. There is considerable disruptions in the supply of power to industries, which is vital for running of the industrial production smoothly. Thus, power disruption (PDIS) in terms of load shedding is regarded as another explanatory variable[139].

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[135] The fluctuations from overall agricultural sector value added over years are estimated from semi-logarithmic trend at 1984-85 prices.

[136] Per capita Net National Product (NNP) at factor costs at constant 1984-85 price is considered (BBS 1992).

[137] Since its inception, in Bangladesh, frequent work strike (*hartal*) called by opposition political parties and trade union activists, has been the most common feature, especially in recent times.

[138] The information on this are collected from daily newspaper (The Bangladesh Observer) over years.

[139] Power disruption, measured in Mega Watt Hours (MWH), are collected from Computer Unit of Generation and Transmission Division for 1987/88-1993/94; that for the remaining years are collected from unpublished documents in the Sales & Accounts Sections of the Central Load Despatch Division, Siddirganj.

8.12.1 The Model

The multivariate model identifying the determinants of industrial production is postulated as follows:

Q = f (FLOOD, AGFL, URBIDX, POLINS, PDIS, INCOME)

Or, Q = A + b(FLOOD) + c(AGFL) + d(URBIDX) + e(POLINS) + f(PDIS) + g(INCOME)

Where,
Q = Production (quantities in relevant units) of selected large industries
FLOOD = Flood Affected Areas (in the country in square kilometres)
AGFL = Agricultural Production Fluctuations
URBIDX = Urbanisation Index,
INCOME = Per Capita NNP
POLINS = Political Instability (in hours)
PDIS = Power Disruption (measured in MWH).

The reference period is 1973/74-1992/93.

8.12.2 Findings of Multivariate Analysis

The findings of the multivariate analysis are shown in Table 8.14. This is evident that most of the industries show high coefficients of determination; out of 14 large industries, 8 show the coefficients significant at 1% level, and 2 at 15% level with only 4 not at any acceptable level of significance.

It appears that flood affected areas have no significant influence on the production of selected large industries[140]. Although for many of the industries the signs of the flood variable coefficient are negative, as expected, none of these are statistically significant at an acceptable level of significance. The coefficient for the sugar industry is found to be significant only at a 20% level. The two industries, namely chemicals and urea fertilizer show significant

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[140] It can be recalled from Table 8.11 that the deviations (from trend of value added) in the industries sector, as a whole, were not inversely (significantly) related to flood affected areas.

Table 8.14: Determinants of productions for selected large industries,1973-92.

					Coefficients of Independent variables					
Industries	R^2	$\bar{R}^2$	Sig. level	D-W Statistic	FLOOD	AGFL	URBIDX	POLINS	PDIS	INCOME
Cloth	.40	.07	.36	1.27	-.051	2.84	-1951.09	2.65	-.478	16.39
Paper	.79	.68	.00	1.85	-.008	-1.52	82.04	-8.89	.33	21.15*
Oil	.45	.16	.25	1.38	-.101	-4.36	-1762.14	21.00	-1.15	41.15**
Food	.74	.59	.00	1.82	-.045	-9.98**	5350.68**	48.18	-.456	97.31
Sugar	.44	.13	.29	1.58	-1.16	-17.99	-652.18	121.34	-.039	66.53
Glass	.82	.73	.00	2.18	-.002	-.047	19.32	.166	-.014	.667
Iron-Steel	.42	.11	.11	1.69	-.880	-19.6	12935.55	-99.29	-.191	-315.56
Cigarette	.20	-.24	.83	2.55	.186	-20.54	3912.53	-80.28	7.89	-156.97
Chemicals	.95	.93	.00	1.97	.020*	.302	628.70**	-.779	-.089	.010
Urea	.94	.91	.00	2.03	3.80*	-28.39	-10033.00	607.43	8.00	1417.62**
Match	.92	.87	.00	1.56	.019	.136	934.85**	-6.32	-.100	-3.03
Newsprint	.73	.59	.01	1.79	.003	-.066	1621.18*	-5.79	-.168	13.049
Yarn	.83	.74	.00	1.49	.000	.001	1.03	.025	.003	.023
P Pump	.54	.28	.13	0.94	.115	1.70	2933.16*	-65.20*	2.40	-40.08

Note : ** Denote statistical significance at 5% level, and * at 10% level.

relationships (at 10%), but unexpectedly, positive relationships for both cases. As argued before, during flood years, the shortfalls in one crop and/or one season are compensated by other crops and/or the next season, through employing some additional efforts, in terms of inputs (eg fertilizer, modern variety seeds and pesticides)[141]. The increased demand derived from the farmers during the flood years might have led the increased production in these two industries.

It was postulated that the variable Agricultural Fluctuation (measured at real prices) will have direct influence on the production of selected large industries. However, despite the fact that the two sectors, agriculture and industry are strongly inter-related (as evident from Table 8.10), the variable Agricultural Fluctuation does not show any significant and positive relationship for any of the industries under study. The sole case of significant (but negative) relationship of agricultural fluctuation with the food industry is contrary to the *priori* expectation. As expected, urbanisation has a generally positive influence on industrial production. A few cases have negative signs, which are, however, statistically insignificant.

As expected political instability, measured in terms of work-strike in hours, has a negative influence, on production, for half the number of industrial sub-sectors. However, the significant relationship applies only to the power pump industry. The coefficients for match and newsprint are significant only at a 20% level[142]. The other industries are not found to have significant relationships since, it can be argued, the large-scale idle-capacity situation generally prevailing in the industries sector in Bangladesh has subsequently helped in overcoming the losses occurred by any such disturbance.

Despite the extent of power disruption varying considerably over years, its coefficients for none of the industries are found to be statistically significant. It may, however, be mentioned that large industries in general have their own power plants to avoid power disruption, which is a common phenomenon in Bangladesh. The prevailing idle-capacity situation might have, again, helped in this regard. As expected, the income variable (per capita income) has a positive coefficient for most of the industries under investigation. Nevertheless, statistically

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[141] The country, endowed with a number of large-scale fertilizer plants has nearly fulfilled the domestic demands.

[142] It may be recalled that the reference period is 1973/74-1992-93; most disturbed period (1994-1996) is not included in the analysis.

significant relationships (at 5%) could be found for oil and urea. The coefficient for paper is found to be significant at 10% level. The industries for which the relationships are significant at 20% level are food and glass.

8.13 Conclusions

What follows from the preceding discussion and analysis is that flood impacts at macro level are actually the net effects owing to deceleration of production caused by disruption of utilities and facilities, on the one hand, and acceleration of production owing to new investment on reconstruction and recovery activities, on the other. While linkage effects can be empirically evidenced at micro-level, albeit crudely, it is a formidable task to assess flood impacts via linkages at the macro level.

The present approach of analysing the macro-level impacts of flooding is open to criticism. First, the deviations from trend estimates are likely to be underestimated and not attributable exclusively to floods as investment cost in the recovery process is not incorporated. Secondly, apart from the distortion of trend estimates due to technological change, the trends are likely to have been underestimated as years severely affected by floods or droughts have not been excluded. In order to have more precise estimates the analysis (especially for industries) thus requires a time series data over a longer period, so that the severe flood or drought-affected years can be excluded when estimating the trends.

Nevertheless, the analysis provides some evidence of the effects of flooding at the national level given the existing linkages in the economy. Although some crops are severely affected by floods, the adverse impact on the total annual agricultural production in Bangladesh appears not to be that severe as is often pronounced. This conclusion, however, is not fully valid as recovery costs are not incorporated in the analysis. In the worst flood year such as 1988 (approximately a 60 year flood), however, the deviation of the wet season rice crop production is 13% below the normal trend while the deviation of the dry season rice crop output is 7% above the normal output trend. The adverse (negative) impacts of flooding on the agricultural sector, as a whole, in 1988 is estimated to be in the region of 5 per cent (below the estimated normal output trend)[143]. Several points may be raised here. Evidently, short falls in production in one rice crop are to a large extent compensated by

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[143] See Hossain (1990), who reached a similar conclusion for food grain production.

above-normal production in other rice crops. As argued before, it is possible that after losing one crop due to floods, farmers augment their efforts on the other, especially the dry season crop which is exposed to less potential risk. Thus, the adverse impacts of floods on the total annual rice production (vis-a-vis agricultural crop production) have not been very severe. The regions might have also played a positive role in this regard, as it is likely that less affected areas, induced by many external factors, offset the losses incurred by severely affected areas.

The fluctuations of wet season rice production, however, are found to be closely and negatively related to flood affected areas, while the fluctuations in value added in agricultural sector, as a whole, are found to be unrelated to flood affected areas.

For industries, the analysis demonstrates that, at least in the short run[144], flooding generally has no great influence on the production of selected large industries. The deviations of the industrial output (from the trend of value added), as a whole, are found to be negatively related with flood affected years, but the relationship was not found to be statistically significant. So far the CMI-small and medium-sized industries are concerned, deviations from productivity trends in all the selected industries are negatively related with flood affected areas. The relationships for only a few industries are, however, found to be significant.

In the worst flood of 1988 the aggregate industrial value added had fallen by 5%, compared to a normal trend output. The value added in the large industry sector has dropped by 11% in that year, while apparently there was no adverse impact on small industries. Fluctuations in agricultural production caused by flooding appear to have no significant effects on production in selected large industries[145].

For industries particularly, it can be argued, the wide-scale, idle-capacity situation prevailing

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[144] Short run effects refer to effects in the same year as flooding. A year-on-year analysis on the time of flooding over the last thirty years shows that most floods (70%) occur during July-September. The production figures also have corresponded to financial years, July-June. The similar analysis conducted of current industrial production with lagged-flood affected areas appears to have not changed the conclusion.

[145] The conclusion, again, is not changed if the current industrial production is analysed with lagged agricultural production.

in the sector might have subsequently pushed the enterprises to compensate the losses caused by floods to a great extent[146]. The adjustment mechanism both in the agriculture and industrial sectors appears to be strong. It is possible that the recovery activities which include immediate measures including government and non-government measures, on the one hand, and the international response, on the other, have been strong enough to have dampened the adverse impacts, especially in the event of larger floods.

On the whole, it appears that flood impacts at the macro level, particularly in the industrial sector, but also in the agricultural sector in Bangladesh, have not been as severe as those at the micro level in Bangladesh. As evidenced earlier in this study, the flood losses at micro-level are enormous, both in terms of absolute and proportional (to asset values) losses. The investigations at micro-level also reveal that the poor and relatively smaller enterprises are more vulnerable to flood hazard. The poorer the household or firm, the higher is the percentage of damage to their asset values[147]. The findings suggest that floods not only enhance poverty but they may help widen the income gap between the rich and the poor.

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[146] In this regard, it may not be out of place to mention a study that has concluded that long run economic impact of a natural disaster such as an earthquake may not be negative but that it is in fact positive (Ellson et al 1983). This was possible due to huge mobilisation of resources into the local-level economy in the USA.

[147] For example, it was revealed in earlier chapters that an average poor household suffered (in terms of losses proportional to values) 4, 5 and 3 times as much, compared to that suffered by a richer household, in a river flood, flash flood and tidal flood respectively.

Table 8.15: Areas affected from flooding in the country over years

Year	Flood affected area (Sq Km)	Affected area as % of total area	Year	Flood affected area (Sq Km)	Affected area as % of total area
1962	37200	26	1978	10800	8
1963	43100	30	1979*	11259	8
1964	31000	22	1980	33000	23
1965	28400	20	1981*	11936	8
1966	33400	23	1982	3140	2
1967	25700	18	1983	11100	8
1968	37200	26	1984	28200	20
1969	41400	29	1985	11400	8
1970	42400	29	1986	4600	3
1971	36300	25	1987	57300	40
1972	20800	14	1988	89970	62
1973	29800	21	1989	6100	4
1974	52600	37	1990	3500	2
1975	16600	12	1991	28600	20
1976	28300	20	1992	2000	1
1977	12500	9	1993	28742	20

Note:

Total area of the country = 56000 Sq Mile = 144000 Sq Km.
* The flood affected areas for 1979 and 1981 are estimated through regression (Aman rice crop damages and flood affected areas).

Source: MIah (1988b); BWDB and own estimate.

CHAPTER 9: CONCLUSIONS

This research set out to investigate a number of broad questions, set within specific boundaries explained in Chapter 1 (Section 1.3). One of the key questions was whether flood loss assessment methods developed in the advanced countries could be applied in a developing country such as Bangladesh. Another broad question concerned whether the non-agricultural impacts of flooding were important in Bangladesh, given that it is continuing as an agricultural economy. In particular, the study sought to investigate whether linkage effects of flooding are important in Bangladesh. The research also aimed to reveal, conceptualise and categorise various non-agricultural impacts caused by different types of floods in urban areas of Bangladesh, and thereby to acquire a knowledge base of the major impacts both at micro and macro level.

This concluding chapter summarises and reviews the major findings obtained from the previous Chapters and, relates them to the major issues raised in Chapter 1. Where appropriate, it also suggests policy implications and recommendations.

9.1 Major Findings

Applicability of the Existing Assessment Methods

The research demonstrates that, with some modifications, the advanced countries-oriented impact assessment methods can largely be applied in a developing country such as Bangladesh. The research examines the practical problems associated with the assessment of flood loss potentials in various urban sectors. Three major problems of flood loss assessment methods are identified: (a) the failure to exhibit relationships of actual damages with flood variables (e.g. depths and durations) (b) converting actual to potential losses through adjustments with damage-saving activities and (c) enormous variabilities in value of properties, stock and damage.

The major areas of differences in the two approaches of flood loss assessments adopted by the UK and present study relate to the technique of assessments, which differs in that the former uses the existing stock position as the reference point, whilst the latter uses actual losses caused by a past event as the reference point. The UK approach adopts the 'average approach' (averaging arithmetically) while the latter employs a different approach - the approach of predicting damages at disaggregated levels through multiple regressions ('regression approach'). The major advantage for the present study is that flood events are not sparse so that direct investigations and subsequent assessments in relation to a past event are feasible. The major advantages of the UK approach is that it requires no adjustments to reduction measures, while the present research requires such adjustments as this is based on actual occurrence.

The synthetic approach of assessing residential damages adopted in the UK or elsewhere in advanced countries is found to be not feasible in Bangladesh. The synthetic approach of flood loss assessments in commercial sectors is also found to be infeasible in Bangladesh, and also in the advanced countries. The major reason is the lack of secondary source information, resulting in the failure to construct a susceptibility matrix for a wide range of damage items. Hence, the study devised assessment methods based on interview techniques in the assessment of flood loss potentials in residential, commercial, office sectors of the urban economy in Bangladesh.

Unlike in the advanced countries, houses in Bangladesh can be categorised into a few broad types (e.g. four types in the main study area), the houses which are lived in by distinctly different socio-economic classes of people. This feature turns out as the major advantage in assessing flood losses based on surveys of actual floods in the residential sector. However, the approach of surveying of actual floods is proved to be expensive. The current study devised methods of damage-data sets construction through multiple regressions ('regression approach'), which is found to be more realistic and cost-effective, particularly in the commercial sectors following wide diversities in commercial activities and large variabilities in damages.

It is argued that dependencies on roads during floods in Bangladesh are likely to be largely offset by 'natural redundancies' created by wide-spread waterways through a large number of water transports. The research therefore seeks to assess only direct damages caused to roads infrastructure. The assessment of flood loss potentials in roads sector has been an outstanding problem. Roads are subject to wear and tear due to a host of external factors, resulting in the failure to precisely segregate repair works attributable exclusively to floods. There exists no research on the methods of assessments of physical damage to roads. The current research adopts a methodology in evaluating direct damage to roads, which involves using time series data on repair costs and then estimating trends. The estimated residuals or the deviations from the trends form the basis of the assessment of direct damages to roads caused by flooding. The establishment of a relationship of these deviations with corresponding flood levels provides guidelines towards assessing potential damages in the sector.

Models Used to Generate Loss Data Sets

One of the main contributions of the study is to construct appropriate potential loss data sets from field level estimates of actual damages, the data sets which are subsequently used as an input to the unit-loss model. Besides the testing of the existing methods, the research develops some new methods of flood loss assessments. The basic principle of the flood loss models adopted by the current research involves seeking statistical relationships with the flood intensity (e.g. depth and duration). The total loss (direct + indirect + multiplier) models in the commercial sector employ combination of unit-loss method, Cobb-Douglas model, multiple regression and input-output model.

Given that relationships of damage with explanatory variables are complex, a variety of functions are tested, both for actual and potential (adjusted for damage-reductions) damages. The models using the 'potential' damages are found to be suitable for use in generating potential damage data sets. Linear models, by and large, do not yield a good fit. The double logarithmic models are found to be more suitable and logical for modelling losses in both residential and commercial sector. Because of the small sample size in the individual groups of properties, the models are estimated with all the properties lumped together, as they portray higher correlations (implying higher explanatory powers of the models). The variables, duration and property type are used as a dummy variable.

Two principal approaches in generating standard damage data sets are examined: the models on absolute losses and those on proportional (to value) losses. In the residential sector, the results show that both the type of models for absolute and proportional damages are suitable for modelling damages. However, it is apparent that the latter models show relatively higher explanatory powers.

Two broad damage components are distinguished while constructing potential data sets in the residential sector: (1) Structural damage and (2) Inventory damage. The residential potential damage data sets are constructed at various levels: (1) per household absolute damage (2) per household proportional damage and (3) per square metre damage. The data sets are constructed for individual house groups and the whole sector, at levels of 5 depth and 2 duration categories.

In the assessments of direct losses to commercial sectors, the proportional approach has not proved feasible, both for industry and business, presumably because not all the direct damage items (e,g. machinery, stock) in the sectors are equally susceptible to water. Instead, the models using absolute damages are generally found to fit well.

There exists a limited number of studies on commercial flood losses. Research on indirect losses is particularly meagre. The current research examines three models for the assessment of indirect losses in the commercial sectors. The first model seeks functional relationship with depth, duration and floor space. The model is not found to fit well for some of the cases with individual groups in business and industries. The Cobb-Douglas production function (hitherto not used in any flood loss research), fitted to the empirical data on capital and labour inputs, is found to fit extremely well in both industries and business. However, the model is constrained by the assumption of constant labour inputs in the post-flood period, the condition which is not largely valid in Bangladesh. In other words, the model would be more suitable in indirect loss assessments providing the changes in the labour inputs in the post-flood period are available. In the third model, indirect loss is found to be related to direct damage in almost all the estimated models. Although the first two indirect loss models can also be used, the third model (having no constraints as the second one) illustrating higher explanatory powers is considered more suitable in the present research.

The research assessed the linkage effects of flooding through construction of output multipliers - an approach so far not been adopted in flood loss research. The output multipliers are first estimated from national I-O Table (with fixed coefficients). But this leads to what theoretically could be the linkage effects of flooding at the national level due to production losses at firm level. Such an approach is potentially inappropriate for mainly the two factors: demand-side factors and recovery/restoration factors. The field investigation shows that a regional economy (town economy in the present study) is considerably resilient. Hence, the output multipliers are adjusted by both demand and recovery factor, which are then used in the assessment of linkage effects.

Five broad damage components are distinguished while constructing potential loss data sets in the commercial sector: (1) Structural damage (2) Machinery & equipment damage (3) Stock damage (4) Production (primary indirect) loss and (5) Linkage effects. Per enterprise and per square metre damage data sets, for individual sub-sectors and the whole sector, are constructed at levels of 5 depth and 2 duration categories.

A comparison of the damageability (e.g. at 0.61 metre depth and 7 days duration) in the four major urban sectors shows that per square metre total damage to office and public enterprise estimates at TK 416, as compared to the per square metre total damage of TK 1217, TK 4323 and TK 213 in the industry, business and residential sector respectively. Per kilometre flood damage in the R & H *(pucca)* roads estimates at TK 33,600 and TK 84,800 in the two floods, 1987 and 1988 respectively. In the case of the Pourasava *(pucca)* roads, per kilometre flood damage is estimated as TK 92,000 and TK 242,000 in the two floods respectively.

The study reveals that clean-up costs as a separate damage component are not relevant in Bangladesh. This is mainly because such costs are often confused with the repair work of floor damage and it appears that the respondents found it difficult to segregate such costs, if any, from the costs of the repair work. Hence, the clean-up costs are combined with structural damages in the current study.

Flood damage assessments are heavily based on many estimation procedures. The various data sets and assessment methods can be used as per appraisal needs and according to basic information available (e.g. floor space or number of properties in the area under appraisal). For a more generalised use (e.g. desk-level appraisal), the sector average can be used, while for a more refined level appraisal, per enterprise or per square metre damage data sets can be used.

Considerable improvements to the quality level of the data sets are feasible by including cross-sectional data, combining all the three study areas. But as the three study areas represent three different floods and the ultimate goal is to perform appraisals of the main case study area, the study generates 'average' potential data sets, specific to only the main case study area representing a river flood. In the absence of cross-sectional data, thus, the generated data sets may suffer from a wider applicability.

Suitability of Regional Flood Loss Models

The research examines the practical problems associated with the applicability of the three regional flood loss models: econometric models, unit-loss models and input-output models. Not all the models are suitable for modelling regional flood losses in Bangladesh conditions. The principal advantage of the econometric model over the unit-loss model is that it can model the full range of impacts, direct and indirect, and can estimate the expected change in the whole economy. The model is, however, not capable of achieving fine-level estimates of flood damages, often required in the flood hazard management. The most important limitation of the model in Bangladesh relates to the unavailability of enormous historical data required for its application in order to model losses at regional levels.

The principal advantage of the unit-loss model over the regional econometric model is that it can provide fine-level estimates for damages, disaggregated over spatial and sectoral properties, even unit by unit. More importantly, the model is capable of separating impacts by types, flood levels and frequencies - even when level and frequency differences are small. The model is thus capable of appraising benefits for a range of flood protection standards, a feature which is inconceivable by any other models. The model is, however, unsuitable for capturing regional impacts in a wider economy, for which regional econometric model is more suitable.

Input-output models, usually used in combination with regional econometric models to assess total impacts, fail to adequately deal with supply side sectors (e.g. transportation). Additionally, these models which are based on fixed input-coefficients, are incapable of incorporating recovery activities.

The unit-loss model, as widely used in the USA or UK, is found to be suitable in modelling regional impacts and thereby appraise town protection schemes in Bangladesh. However, the model has the limitation in that it is incapable of adequately modelling the total changes in the whole economy. The construction of multipliers and their incorporation into the assessment procedure is likely to surmount the problem, but the very construction of the multipliers at regional levels is beset with problems.

The successful application of the unit-loss model heavily depends on the fine-level potential damage data sets and accuracy of land use and land level survey, on one hand, and high-quality, detailed-level hydraulic and hydrological information, on the other. In Bangladesh, the construction of high-quality, fine-level standard damage data sets appears to be feasible, but accomplishment of the other two components of the model has some limitations. Hence, in Bangladesh conditions, the unit-loss model appears to be more suitable for up to an intermediate scale project appraisal.

Revealing of Flood Impacts at Micro-level

The research is but a 'demonstration' of the testing of the existing methods of assessments. The study, the first of its kind in Bangladesh, seeks to reveal, categorise and conceptualise various urban and non-agricultural impacts of flooding.

Residential Sector

Impacts by Socio-economic Classes

The study reveals that the low-cost houses (and thus low-income occupants, as the low-cost houses correspond to low-income classes) are relatively more vulnerable to floods. The analysis manifests that the lower the level of house categories (and income classes) the higher the percentage of damages to their total asset values. For example, in the major river flood, the percentage of damages to asset values in the house categories BB , BC, MC and MT are 7.3%, 10.7%, 11.2% and 26.2% respectively. In the case of tidal flood, the corresponding percentages are 23%, 32%, 55% and 64% respectively. Similar findings hold good in the case of the flash flood.

This finding well corroborates the general contention that the poorest people are the most vulnerable to floods - they have the most to lose in proportional terms. Thus the poverty syndrome is directly related to vulnerability and flood disasters may be found at the interface between flood hazards and vulnerable conditions (Davis 1978; 1981; 1984a; 1984b; Blaikie et al 1994; Chan 1995).

As regards susceptibility of building materials to floods in the residential sector, again, the research reveals that the lower the costs of construction, systematically higher are the structural damage proportions (to values). For example, for the lowest-cost house type, MT, the percentage of structural damages (to value) amounts to in the range of 28%, 32% and

69% in the three floods respectively (river, flash and tidal flood), as against 5%, 1% and 14% for the highest-cost house type, BB. One is thus tempted to conclude that inexpensive building materials are more susceptible to floods.

Differential Impacts by Flood Types

The research addresses the differential impacts caused by the different types of floods in Bangladesh. The analysis reveals that the damages caused due to different types of floods are significantly different. For example, the per household actual damage (total damage averaged over all house types) amounts to about TK 19,000 in the case of the major river flood, as against TK 10,000 in the flash flood and TK 62,000 in the tidal flood. In terms of proportional (to value) damages, again, it is revealed that the most devastating is the tidal flood, which destroys about 34% of the total value. This is followed by a flash flood which accounts for 11% of the total value, as against 10% in the case of the major river flood.

Damage Components

In all the flood types, inventory damage is the major damage component in the total residential damage, accounting for 43%, 34% and 47% in the river, flash and tidal flood respectively. The next major component is the structural damage accounting for 31%, 27% and 36% respectively in the three types of flood. Damage to trees, gardens and livestock is also considerable.

Perception, Warning and Human Factors

The analysis reveals that the individual perception and human factors are important in explaining flood damage and to the hazard preparedness process. The analysis suggests that the level of perceptions among floodplain users in Bangladesh is high, which has a positive bearing on the resilience-building or the vulnerability-reduction process. Although, generally, warning has some damage-reducing effects, formal warning systems in Bangladesh often do not perform satisfactorily. However, the local knowledge process and informal warning systems, essentially developed through floodplain occupants' own perceptions and judgements, appears to play an important role in the damage-reduction decision making process. Similar view is suggested by Parker and Handmer (1996), who highlights the need to recognise the reality of informal warning systems in the UK. Community cohesion along with family kinship and household structure also play a significant role in the positive response to flood hazards.

Perception capability appears to be linked to the size and the type of floods. In a large river flood, the occupants have higher scope of perception through a range of information networks including the awareness of the rising river levels and dissemination process within the community members. Flash floods (e.g. flash or tidal flood) provide relatively limited scope for perceptions. The flood-to-peak interval and the state of awareness of the distance of the advancing flood water from property locations appear to have a crucially important bearing upon perceptions and subsequent damage-reduction decision-making process.

The adjustment strategy to flood hazards in all the study areas appears to be characterised by the measures, of bearing the loss and/or emergency actions including some compensation measures. The adjustment strategies regarding the damage-savings of inventory damages are highly successful. As in damage reduction activities, community ties and friendliness play a vital role in the compensation and recovery activities.

Commercial Sector

Damage by Type of Activities

In commercial sectors, the analysis of both industrial and business units manifests enormous variations in damage figures among the type of enterprises. In industries, engineering & electrical, food & agro-based, and timber & furniture units are generally the more affected group of industries. In business, generally the food & grocery, electrical & electronics, and motor & cycle parts units suffer more.

The study reveals that the small-sized enterprises (for particularly industrial units, categorised capital-wise) tend to be more vulnerable to flood hazard. This finding corroborates a similar finding achieved for residential properties that the poorest people are the most vulnerable to floods. The analysis also concludes that the relatively lower capital-intensive industries (which are largely small-sized industries) are subject to higher flood losses.

Differential Impacts by Flood Types

The research manifests, for both industries and business, significant variations in damages caused by different types of floods. In industries, for example, the tidal flood causes nearly 4 times as much the damage caused by the river flood. Averaged over all types, per industry potential damage is in the range of TK 148,000 in the major river flood, as against TK 65,000 in the flash flood and TK 587,000 in the tidal flood. In proportional (to value) terms, again, the more devastating is the flash and tidal flood, which destroys about 46% and 41% of total value respectively. Despite the fact that the major river flood has a much longer duration, the flood damage accounts for 17% of the total value of assets in industries.

In business enterprises, again, the tidal flood is the most destructive. An average business unit suffers damages to the tune of TK 105,000, TK 40,000 and TK 250,000 Taka in the major river, flash and tidal flood respectively. In proportional (to value) terms, the damages in the three floods estimate as 31%, 26% and 53% respectively.

Damage Components

Among the direct damages, stock is the most severe component in the case of all the flood types. In industries, this accounts for 24%, 17% and 65% in the total damage in the river, flash and tidal flood respectively. In business units, stock damage comprises 57%, 53% and 47% of the total damage in the three floods respectively.

Considered of all the damage components, direct and indirect, indirect damage generally constitutes the major part in the total damages, accounting for 57%, 47% and 26% in industries in the three floods respectively. In business units, the contributions are 39%, 40% and 41% in total damage in the three floods respectively.

Linkage Impacts of Flooding

The output multipliers (adjusted for the recovery and decline in demand) are used for the assessment of linkage effects of flooding. Unlike in many countries (e.g. USA), the linkage effects of flooding in industries in Bangladesh appear to be quite high, estimated in the range of 61% of indirect loss (output loss). The maximum effects occurs in cotton & textile industries (79%), while the minimum occurs in food and agro-based industries (29%).

'Ripple' Effects

The study reveals that the impacts of flooding considerably faded with geographic and economic differences from the flood events. Thus the 'ripple' effects of flooded enterprises for both industries and business decline gradually from town and region and in the country, as a whole. In both industrial and business sector, the country, as whole, can make up about 48% of the total production loss suffered by the sample firms. The net output loss suffered by industries and business at regional and national level are much lower in the case of the flash or tidal flood compared to that in the major river flood. This is understandable in that in the case of the wide-spread river flood the scope of recovery at the regional or national level is likely to become more limited. In the case of isolated and localised floods (e.g. flash or tidal flood), on the other hand, the scope for recovery is likely to be higher through resource mobilisations from other parts of the country.

Assessment of Flood Protection Benefits

The research carries out a case study on Tangail town, which demonstrates the application of the generated flood loss data sets and the unit-loss model through providing an example of actual appraisal of a flood protection proposal in Bangladesh.

The total urban flood loss predicted in a 2 year flood in the Tangail town is about TK 90 million, which increases to about TK 481 million in a 5 year flood, followed by TK 814 million, TK 1029 million and TK 1271 million in a 10 year, 20 year and 40 year flood respectively.

The expected annual benefit of protection estimates as TK 248 M. The annual overstandard benefit estimates as TK 32 M, so that the total expected annual benefits increases to TK 280 M. The present value of benefits of the flood protection at a 10% discount rate estimates as TK 2456 M (approximately £M 37.8 @ TK 65) to a 40 year standard.

The estimated present value of benefits per exposed ground-floor property amounts to TK 95,823 at a 10% discount rate, with a 50 years scheme life. The sterling equivalence for the estimate is £1474 respectively.

Relative Vulnerability of Urban Sectors

The case study on Tangail shows that the residential sector is the most vulnerable in the whole urban economy, accounting for the major proportion in the total urban loss, about 57%. The proportion of industrial damage in the total urban loss amounts to about 21%, while that for the business accounts for about 20%. The damage to office and public buildings sector, constitutes about 1.4%, while that for the roads sector accounts for 0.6% in the total urban loss.

A comparison of the damageability per square metre (total) damage shows that the business sector is the most vulnerable, followed by industries, office and residential sector respectively. Averaged across damage components, the damage component inventory/stock accounts for the highest proportion e.g. 65% in the total urban loss. This is followed by the structural damage component, constituting about 16%. Primary indirect loss constitutes 12%, machinery/equipment about 3.3% and the linkage effects constitutes about 4% of total loss in the urban economy.

Importance of Non-agricultural Impacts of Flooding

In Bangladesh, the industrial and service sector has a large unfulfilled development potential, which is expected to grow in urban areas due to the presence of better infrastructural facilities. Yet induced by rural-urban migration, this might lead to even a greater increase in the current rate and level of urbanisation in the near future. Given that a 'strong relationship exists between economic development and urbanisation' ((Samuel 1986), potential urban flood losses would become more and more important in Bangladesh in the years to come.

The research demonstrates that the size of non-agricultural impacts of flooding in Bangladesh is enormous. An average household is subject to a potential damage in the range of up to more than 34% of total asset value, depending on the type and depth of flood. In particular, the damage items such as trees, gardens, livestock, and 'other' houses are found to be highly susceptible, to the extent up to more than 90% of the total value. An industry is subject to a potential damage up to a more than 46% of the plant value, and a business enterprise up to a more than 53% of value, depending on the type and depth of flood. The analysis on agriculture sector at the macro level, on the other hand, depicts that during a 30 year period flood damage to all rice crops (major contributor to agriculture) estimates less than 4% of the total potential output. If vulnerability could crudely be defined as proportional damage to asset values, the study reveals that non-agricultural sectors vis-a-vis the urban sectors are highly vulnerable to floods, almost the only natural hazard assuming threat to such sectors in Bangladesh.

Revealing of Flood Impacts at Macro-level

The study addresses the research question of whether linkage effects of flooding at the national or regional level are important in Bangladesh. Hitherto, there is few research investigating linkage effects of flooding at the micro or macro level. In the current research, it is argued that the issue of flood impacts at the macro level and the existing linkages in the system are interrelated. Based on time series data, collected from secondary sources, the analysis is carried out by estimating trend on output, value added and prices on two broad sectors of the economy, agriculture and industry.

It is revealed that in the major flood years, the deviations of the wet-season rice crops (Aman+Aus) have fallen below the normal production trend while the deviations of the dry-season rice crop (Boro) are above the normal output trend. In the worst flood year such as 1988 (approximately a 60 year flood), for example, the deviation of the wet season rice crop production is 13% below the normal trend while the deviation of the dry season rice crop output is 7% above the normal output trend. The adverse (negative) impact of flooding on the value added of the agricultural sector, as a whole, in 1988 is estimated to be in the region of 5 per cent (below the estimated normal output trend). Both for Aman individually and wet-season (Aus + Aman) crops together, the correlations of the deviations with flood affected areas are found to be negative. For the dry season crop (i.e. Boro) the correlation is found to be positive.

This suggests that the shortfalls in wet season rice crops are largely compensated by increased production in the dry season rice crop in the same year[148]. It is possible that after losing one crop due to floods, farmers augment their efforts on the other, especially the dry season crop which is not exposed to much potential flood risk. Thus, the adverse impacts of floods on the total annual rice production (vis-a-vis agricultural crop production) have not been

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[148] This conclusion was also reached by studies such as Hossain (1990) and ADB (1994).

much severe. The regions might have also played a positive role in this regard, as it is likely that the less affected areas, induced by external factors, offset the losses incurred by severely affected areas. The recovery process is likely to be facilitated by increased provision of irrigation and modern inputs and other extension services.

For industries, the analysis demonstrates that, at least in the short run, floodings generally have no great influence on the production of selected large industries. The correlation of the deviations of the industrial output (from the trend of value added, as a whole) with flood affected years is not found to be significantly negative (in statistical sense). The analysis of productivity on the CMI-small and medium-sized industries also provides a similar finding. In the worst flood of 1988, for example, the aggregate industrial value added have fallen by 5%, compared to a normal trend output. The value added in the large industry sector dropped by 11% in that year, while apparently there is no adverse impact on small industries. The analysis shows that fluctuations in agricultural production caused by flooding have no significant effects on production in selected large industries.

For industries particularly, it can be argued, the wide-scale, idle-capacity situation prevailing in the sector might have subsequently pushed the enterprises to compensate the losses caused by floods to a great extent. The adjustment mechanism both in the agriculture and industrial sectors appears to be strong. The above conclusion, for both agriculture and industries sector, is not, however, fully valid as investment costs in the recovery process are not included in the analysis. The macro level impacts, which are actually the spill-over effects due to various factors, including linkages in the economy, are not a true measure of the flood impacts. The spill-over effects include a combined effect of a number of factors, such as resource mobilisation (foreign and domestic), linkages (e.g. economic, socio-demographic and regional), demand and supply factors and recovery activities.

9.2 Limitations of the Research

The research, constrained by time and resources, is but a 'demonstration' of the testing of the existing assessment methods. The study carries out investigations in three case study towns, representing three different floods. It is not so appropriate to draw wider conclusions for flood losses and their assessments elsewhere in Bangladesh from a single case study, based on the evidence from a small sample size at that. However, in the particular range of social, economic and flood conditions the flood loss data sets can fairly be generalised.

The research suffers from the availability of quality and detailed level information of hydraulic and hydrological information, which might have affected the precision of the estimate of benefits of protection. For much the same reason, the research has not sought to construct damage data sets for highly disaggregated levels of flood duration. The field survey demonstrates that the flood duration variable is quite sensitive to the annual benefits of protection. However, this has been an outstanding problem in flood loss research, as floods are defined by depths rather than durations. It is not known from the past history, for example, as to what floods lasted for what durations. Furthermore, as it is precisely not known as to what individual properties in various locations were flooded with what durations in different past floods, the estimate had to depend on some set assumptions. This might have affected the final benefit estimates.

The approach of analysing the macro-level impacts of flooding is also open to criticism. The deviations from estimated trends are likely to be underestimated as investment costs in the recovery process are not incorporated. Apart from the potential distortion of the trends due to technological changes, the trends are likely to have been underestimated as years severely affected by floods were not excluded. In order to have more precise estimates the analysis (especially for industries) thus requires a time series data over a longer period, so that the severe flood years can be excluded when estimating the trends.

9.3 The Research Implications

9.3.1 Implications of the Research in Policy Formulations

The research which devised flood loss assessment methods and generated potential damage data sets is expected to be used as a guide which will help comprehensively appraise both urban and agricultural protection schemes in Bangladesh. The revealed flood loss information in various urban sectors can be used as a basis in the policy formulations towards protecting urban centres vis-a-vis non-agricultural sectors.

The perspective associated with agricultural and urban flooding is different. Whereas the scope for coping with agricultural flooding is higher (e.g. through changes in cropping pattern), urban and commercial growth centres are not likely to have that degree of flexibility against floods. Controlled flooding is obviously not an appropriate strategy in urban areas, as often the case in agriculture. Most agricultural protections are often relatively large projects. In contrast, the protection schemes for the densely populated and built-up urban areas containing a large number of properties are often relatively small in size. External harmful impacts including environmental damage in urban protection is likely to be minimal. Floods are almost the only natural hazard that can pose significant threats to non-agricultural sectors in Bangladesh.

The case study on the Tangail town (which is a typical urban area) protection indicates that the benefits of protection far surpassed the cost of protection[149]. In this context, reference can be made of a study, FPCO (FAP-12, 1992), which estimated IRR in 17 agricultural FCD/I projects, out of which only nine are assessed as economically viable (IRR over 12 per cent). Some of those projects that were not viable had IRR either negative or close to zero. This indicates that from an economic point of view, the protection of urban and commercial centres in Bangladesh demands a high priority. Given the scarce-resource situation in Bangladesh, selection of projects is crucially important. The research demonstrating the use of unit-loss model enables identifying a range of schemes and standard of protections from which an appropriate choice and priority is feasible.

The strategic issue of the balanced choice of structural and non-structural flood mitigation deserves a careful consideration. Structural measures have the limitations in that such measures more often invite settlements in hazardous areas, potentially creating the ever increasing problem of urbanisation. The structural measures heavily dependent on external aid are costly, induced by aspects such as long- gestation periods, recurring operation and maintenance costs and the need for the provision of drainage system. In spite of this, there is a tendency for engineers concerned with floods to think primarily in terms of engineering solutions (Parker and Harding 1978). Bangladesh appears not to be an exception to this, where both engineers and international donors have the tendency to favour the engineering-oriented capital works and visible projects.

The research explaining flood loss variations lay great importance on non-structural measures such as warnings, perceptions and emergency preparedness. It is revealed that the majority of sample floodplain occupants have employed some measures to reduce at least inventory/stock losses. In the case of the major river flood (Tangail town), for example,

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[149] Benefit-cost analysis is not within the purview of the current research, but an approximate estimate of financial cost of protection is calculated, in order to facilitate a preliminary comparison with benefits.

even in the absence of warnings, considerable damage savings are made through a high level of awareness, perception, informal and personal networks. In particular, a long time-to-peak floods in the case of major river flood allows the occupants to adopt substantial damage-saving measures. At least for this type of flood, the survey reveals that simply checking rising river-levels can help save substantial stock/inventories through undertaking loss-reduction measures. In the third case study area, nearly no loss savings were possible primarily because few people believed the warning message. Lack of emergency preparedness (which needs to exist at local levels), including infrastructural adversities (e.g. power failure, lack of transports facilities and the abrupt shortage of workers) also contributed significantly to the vulnerability of especially the industrial and business enterprises.

The damage-reducing effects of flood warnings are well documented (e.g. Penning-Rowsell et al 1978; Parker 1991b), but the warnings in Bangladesh need to be effective. If the public has no confidence on the warning message issued, then the system will not work regardless of how sophisticated it is. A 'false' warning can have adverse effects on future warnings. This was the case in the Bahubal case study (flash flood) area where a considerable number of people kept idle without believing the warning message because of a false warning issued few days before in an earlier case which did not actually occur. In Khatunganj (tidal flood) area, very few people believed the warning while some could not understand the language of the warning signals issued.

Flood proofing of residential structures appears not to have been a popular measure of minimising flood losses in the sample urban areas. In the Tangail study area, however, since the 1988 disastrous flood some households (low-cost houses in the riverine locations, in particular) are in the practice of giving flood walls (or 'dua' as they call) around plinths by bamboos to protect from potential erosion of floors and walls. Since then, people have become more aware of any potential disaster in the future. Some has started to raise ground and floor levels of their properties, especially in the new constructions. It is important to rely on traditional mechanisms and help individuals more effectively respond in the way that they prefer. It is therefore important to understand how individuals respond to disasters and select some form of response strategies that prove effective. As an illustration, housing Third World disaster victims in western-styled prefabricated houses is one of many examples of ineffective official strategies (Davis 1978). Understanding individual perception (including beliefs, attitudes and expectations) can help floodplain managers plan and choose reduction strategies that can complement individual responses. Although flood hazard awareness and public education programmes have often been documented as less successful (Handmer and Milne 1981; Fordham 1992), they remain important instruments which, when planned carefully can effectively reduce losses resulting from hazards and disasters (Davis 1982; Smith 1992).

The current research acquired knowledge of the vulnerability of urban sectors, which has a bearing towards a rational allocation of resources in a flood ravaged economy. The analysis will facilitate identifying bottlenecks of industrialisation, in particular, with regard to flood losses. One way of reducing vulnerability among poor flood victims may be through extending subsidised credits to those who have limited access to institutional credits. Insurance can be an effective flood loss reduction strategy (Harding and Porter 1969; Burton et al 1993). Flood insurance is potentially a good measure for absorbing losses from especially high-magnitude, unpredictable floods. Many parts of the developed world have subsidised flood insurance schemes (e.g. in USA). Ironically, the insurance industry is largely underdeveloped in Bangladesh. There is almost no flood insurance on properties, let alone any subsidies given to them. There is little legislation on flood insurance and the insurance companies are barely interested to developing flood insurances, presumably due to a high incidence of flooding in the country. The government policy should be directed to encourage companies to draw up flood insurance schemes. Property-owners should also be made aware and encouraged so that they insure their properties. The introduction of insurance schemes mean not only disaster prevention and mitigation but also they may help towards increasing general awareness and perception, through educating people what a natural disaster can do to a community and individuals.

In the context of population pressure and scarcity of land in most urban areas, the prospect of land use control, which has been used as an effective way of reducing flood vulnerability in many western societies does not seem to be promising in the urban areas in Bangladesh. Nonetheless, attempts should be made to introduce land use regulations, where feasible, to discourage any further encroachment in the flood-liable lands.

Given the scarce-resource conditions in Bangladesh, a balanced choice of mitigation strategies - structural and non-structural - is crucial. No measures are foolproof. Even structural measures cannot lead to a full protection. The study demonstrates that considerable flood reductions are feasible through non-structural measures which involves less costly investments. Even the level of awareness and perception which involve nearly no costs can lead to substantial damage-saving actions.

The study devised methodologies through which prioritisation of projects and choice of schemes is feasible. The study demonstrates different flood loss potentials in three different floods. The knowledge of the comparative costs and benefits of the alternatives would help identify which urban centres should be protected through structural measures and which need to be protected through improving forecasting and warning systems, and emergency planning, for example. Flood warning systems are currently under-developed as are other measures such as emergency preparedness, legislation and land use regulations. The study provides evidence that effective warning along with the emergency preparedness can reduce enormous flood losses in tidal and flash floods, especially in the commercial sectors.

It is never feasible to eradicate floods from Bangladesh, but it is important that they are managed successfully. Emergency reliefs are not, and should not be a strategy towards flood recoveries. It is important that relief works calling upon pressure on development and aid resources are designed to evolve into development works. There are success stories[150] in Bangladesh which suggest that 'well-conceived' emergency operation in the wake of flood disasters substantially restore the local economy, through providing reliefs in the form of wages to repair the damaged embankments (Rab 1992; Hyder 1996) (See, also, e.g Clay 1986; Shaw and Clay 1993). The post-disaster relief works when integrated with the main stream of development-oriented works (public works through food-for-work operations, for example) is expected to provide the 'emergency windows' i.e. a quick and 'effective response to an emergency' (Clay 1985), which in turn will contribute towards a better floodplain management in the country.

9.3.2 Implications of Global Warming for the Research

The research provides some implications with regard to climate change and global warming in economic analyses of investments in flood protection in Bangladesh. The potential for global warming and subsequent sea-level rises is increasingly a concern to the international and Bangladesh community. The issue of global warming in Bangladesh context is well

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[150] In the aftermath of 1991 tidal flood, an investment of 35,000 tonnes of wheat, provided as wages to rebuild the damaged embankments, enabled the farmers to produce 170,000 tonnes of rice (Rab 1992).

documented in some recent studies such as Asaduzzaman (1993); ADB (1994); Ahmad et al (1996); Warrick and Ahmad (1996), Kausher et al (1996) and Brammer et al (1996). There are apparent differences of opinion about the nature, extent and speed of the changes associated with global warming. However, there is general agreement that the issue has provoked serious problems towards achieving sustained and environmentally sound economic and social development particularly in developing countries. The country report by ADB (1994) suggests that although in terms of carbon dioxide emissions Bangladesh ranks among the lowest ones and there has been little evidence of any increasing trend in average temperature, rainfall shows definite trends of increase. Ahmad et al (1996), however, suggests that over the past 100 years, Bangladesh has warmed by about 0.5^0 C. The global climate model results show that for the IPCC (1990) BAU emissions scenario, Bangladesh is projected to be warmer by up to 2^0 C than today by the year 2030[151]. The potential for a future sea-level rise associated with global warming is of great concern to Bangladesh, a developing country with vast low-lying, densely populated coastal areas. Additionally, various studies suggest that the mean annual rainfall in and around Bangladesh would increase with global warming (ADB 1994; Ahmad et al 1996; Brammer et al 1996). The increased rainfall in the future may be expected to lead to increased surface run-off inducing increased frequency and severity of floods in the country.

About 11% of the country's land area is likely to be affected if a 45 cm rise of sea level occurs by 2070. A one metre sea-level rise will submerge more than one-fifth of the country's area (ADB 1994). In the face of this situation, the coastal and low-lying regions of Bangladesh will be worst affected. It is anticipated that a 45 cm sea level rise along the Bay of Bengal coast in 2070 will submerge 11 Districts (including perhaps the District and other small towns). Under these Districts, 38 Thanas (including Thana headquarters and semi-urban areas) will then be at risk. Additionally, it is of great concern, from the economic point of view, that the two important port cities will also be under severe threat. In the backdrop of this situation, the rate of out-migration from rural areas in general and the coastal areas in particular is expected to further increase. Thus, in Bangladesh climate change may lead to further increase in already rapid rates of urbanisation. In particular, the larger and less exposed towns elsewhere in the country will be overcrowded at a much faster

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[151] The International Panel on Climate Change (IPCC) estimated this with a "business-as-usual" (BAU) (i.e. without any policies to reduce emissions) scenario of greenhouse gas emissions; the world is projected to be 3.3^0 warmer by the end of the next century (Ahmad et al 1996).

rate. Following this, either the coastal towns will have to be protected through costly measures or mass evacuations will have to be undertaken.

The above discussion suggests that the potential increase in flood frequency and severity, on one hand, and future urbanisation (induced by sea-level rise), on the other need to be taken into account in the long-term flood mitigation planning strategy. The inhabitants in particularly coastal areas will be increasingly under threat from especially tidal flooding. The various studies point to the fact that there is a serious lack of fundamental knowledge concerning the link between climate variations, flood conditions and socio-economic effects. Understanding of the degree of vulnerability to different climate and flood conditions and the ways in which local people are able to cope with the situations is fundamental to consideration of policy development and strategy implementation designed to reduce vulnerability. While the protection from flooding is already a major government policy this may now assume high priority. Thus the knowledge base of flood loss potentials by different types of floods acquired in the current research is expected to have important implications for flood mitigation policy development and economic analysis of investments in flood protection. The current research indicates that flood loss is usually quite sensitive to even small changes in flood levels (See Section 7.2.2.1 in Chapter 7), and flood levels are expected to gradually increase with global warming. The potential standard loss data sets constructed for various disaggregated flood depths and durations will contribute to an understanding of the changing vulnerability of properties to flooding over time. Vulnerabilities of properties vis-a-vis today's potential flood losses will need to be factored with some appropriate coefficients to incorporate the potential sea-level rise as well as future economic growth.

9.3.3 Implications of the Research in Relation to FAP Guidelines/FAP Studies

As mentioned in Chapter 2 (Section 2.2.6), there exists a number of documents in the form of guidelines on appraisal methods and economic analyses for FCD/I projects. The documents include FPCO Guidelines for Project Assessment (1991a; 1992e); Shahabuddin and Rahman (1992); and GOB-Republic of France's Pre-feasibility Study for Flood Control (1989). Annex-3 of the FPCO Guidelines outlines some general principles on the post-project assessment of non-agricultural/fisheries flood damage, principally concerning direct benefits from flood protection. A detailed review of the guidelines recommended in the above mentioned documents is presented in Chapter 2 (Section 2.2.6). The guidelines are largely concerned with appraisal methods of agricultural protection, but concentrating on various costs, such as economic prices of commodities and conversion factors. Although non-agricultural damages are recommended for inclusion in the economic analysis, almost no guidelines on methods of loss assessments, let alone on non-agricultural losses, are covered in any of the guidelines. On the other hand, as the current research clearly demonstrates, flood loss potentials (direct, indirect and linkage effects on various non-agricultural sectors) are enormous, which are expected to further increase with the growth of the sectors in the years to come.

Additionally, as discussed in Chapter 2 (Section 2.2.6), a number of feasibility studies for town protection has been carried out in the recent past (FPCO, FAP-8A 1991b; FPCO, FAP-8B 1991c; FPCO, FAP-9A 1992f; BWDB, FAP-9B 1992; GOB-UNDP, 1992). The non-agricultural flood loss assessment methods adopted in these studies have been examined in details, which demonstrates the implications of the current research.

It is evident that, presumably because of the lack of consistent and adequate guidelines on loss assessments, the studies have not adequately dealt with benefits of protection due to non-agricultural sectors. In none of the studies, potential loss data sets by depths or durations, by sectors or sub-sectors are constructed. Almost all the studies use flat rates (fixed ratios) to assess both direct and indirect damages to properties, irrespective of type and size of properties. In the absence of any information on land levels and properties' heights and hence any knowledge of the extent of inundation caused to various types of properties by a range of floods the benefit assessment is certainly associated with gross estimation errors. This is more so following that in Bangladesh small differences in flood levels can be significant in terms of area and properties affected and damages caused[152].

The current research demonstrates that the non-incorporation of factors such as 'average remaining values' of the properties, output recoveries and trade adjustments by commercial enterprises will lead to substantial over-estimation of damages. The research clearly shows that the variations of susceptibilities and damages, both within and among groups of properties, are enormous. This is more so for business and industrial enterprises. Similarly, flood damages are significantly different (at times many-fold) among different socio-economic

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[152] For example, in the main case study town (Tangail), the difference in level between a 2 year and 5 year flood is 50 centimetres, while the properties flooded by the two flood types are 19 and 73 per cent respectively (See Section 7.2.2.1 in Chapter 7).

class of households and size and scale of enterprises. Hence, the use of flat rates across all properties inevitably leads to a considerable over-estimate of benefits.

What this brief discussion implies is that, as there exist no consistent flood loss assessment methods nor any regional loss models, or any reliable potential standard flood loss data sets in Bangladesh, the appraisals of FAP and other projects have been subject to substantial inadequacies. In particular, the urban flood damage data produced or estimates of urban damages avoidable from protection, carried out by the studies appear to have serious limitations. The current research overcomes many of the existing shortcomings of data and methods/models. The principal achievement of this research is that flood loss potential for urban sectors has been investigated and devised, providing flood loss data of a significantly higher quality that has been available hitherto in Bangladesh. In providing these data the research is a significant advance upon the methods recommended within the existing FPCO Guidelines for project assessment, and those used in recent FAP urban protection studies. Thus the research is expected to be used as a guide to facilitate towards appraising both agricultural and urban protection in Bangladesh more comprehensively in future. Indeed, FAP-12 (1992) study in its concluding remarks has stressed serious needs for such data and methodology in Bangladesh.

9.3.4 Implications of the Research on Cost-benefit Analysis

The research also provides some implications with regard to the principles of benefit-cost analysis (BCA), the technique which is defined as 'an economic technique designed to compare inputs to measures (costs) and the resulting outputs (benefits)' (Davis et al 1987). The technique is widely used towards taking decisions for the most 'efficient' project from different alternatives, from economic point of view. Thus the conventional economic efficiency and BCA analyses lead to the favouring of the densely-built up areas (viz. the major cities), with inevitably the poor and sparsely populated urban areas being neglected and unprotected. For much the same reason, the poorer section of the society are set to be neglected and not incorporated in the conventional BCA analysis. The current investigation reveals that the poor and relatively the smaller enterprises are more vulnerable to flood hazard. The poorer the household or firm, the higher is the percentage of damage to their asset values. Thus they are worse off in proportional terms. They are also worse off in linkage terms. Price hikes compounded by abrupt fall in employment and real wages in the aftermath of floods (Sen 1981) hit the poor in the worst way. In effect, this causes malnutrition, and the existing poor health of the poor further deteriorates, with the likelihood of many becoming crippled in the long run. On the other hand, 'Poverty is one of the main reasons why many people persist on hazardous floodplains', and they have 'little locational choice' (Chan 1995). As the poor are not equipped to cope with floods, they become poorer because of their poverty, suggesting that disasters and poverty operate in a vicious cycle. Therefore poverty which is caused due to the lack of access to resources is a fundamental cause of hazard vulnerability among specific groups in society (Davis 1978; 1984a; 1984b; Blaikie et al 1994).

The idea is not entirely unfamiliar[153], but the study findings reenforce that the primary and long run indirect effects of floods on the poor need careful consideration when formulating mitigation plans. From the social point of view, flood management policies should direct to some sort of weighting system so that the poor are protected. Thus, project appraisal methods using conventional 'economic efficiency analysis' need to be calibrated in order to confront the problems relating to the sustainability of development.

Bangladesh is a typical example of a developing country, having indeed nearly all such characteristics as high population and urbanisation growth and low per capita income, with an acute unequal distribution of resources. Disasters creation is closely related to vulnerability of population at risk and natural hazards. Vulnerability, on the other hand, is associated with many social, political and economic factors such as lack of access to resources and power structure. Floods or any natural hazards are only one factor which, however, acts as a catalyst towards creating disasters. Hence, the research implies that any comprehensive natural hazard management in a developing country like Bangladesh is required to simultaneously address the 'root causes' (Blaikie et al 1994; Rahman 1996) contributing to disasters creations.

9.4 Future Research Directions

Flood protections are expected to create increased urbanisation - the urbanisation which is but an 'inevitable concomitant of industrialisation' (Ranis et al 1990), in turn giving rise to

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[153] For example, Parker and Thompson (1991) suggested that 'the research literature on hazard impacts and responses is heavily oriented towards wealthy societies and there is need to reconceptualise flooding impacts and responses'. See also Penning-Rowsell et al (1983); Penning-Rowsell and Green (1990).

pressing vulnerability of the occupants. However, flood protections have an important role in future economic growth through protecting industries and other commercial activities. Hence, the interface between the flood protection and disaster vulnerability (via urbanisation), and urbanisation and the economic growth (via industrialisation) merits pursuit in the future research.

Following that the findings relating to the flood impacts at the macro level are indicative, such impacts need to be critically verified in a future research, taking into account of all the related factors, such as investment costs and other costs of recovery, foreign and domestic resource mobilisation, economic and other linkages in the system.

The study reveals that flood impacts at the macro level, particularly in the industrial sector, but also in the agricultural sector in Bangladesh, have not been severe. The flood losses at the micro-level, on the other hand, are enormous, both in terms of absolute and proportional (to asset values) losses[154]. The findings suggest that floods not only enhance poverty but they may help widen the income gap between the rich and the poor[155].

This dilemma poses further research questions and analysis relating to who loses and who gains from floods in the long run. The distributional effects of flood impacts are important as, these are related to equity, which, in turn, is associated with sustainability of development. Many problems of sustainable development and environment 'arise from inequalities in access to resources'[156], and presumably, the problems are escalated by the existing poverty and skewed distribution of resources in Bangladesh. Thus, further study is needed to investigate the distributional impacts of flooding in order to confront the problems relating to the sustainability of development, especially in the context of Bangladesh socio-economic and flood conditions.

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[154] For example, it was revealed that an average poor household suffered (in terms of losses proportional to values) 4, 5 and 3 times as much, compared to that suffered by a rich household, in a river, flash and tidal flood respectively.

[155] In agricultural projects as well (e.g. Chandpur FCD/I Project), Thompson and Penning-Rowsell 1991b) concluded that the 'overall gains from the project have not been evenly distributed'.

[156] Brundtland Report (1987), Our Common Future (The World Commission on Environment and Development.

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APPENDICES

APPENDIX A: APPENDIX TABLES AND FIGURES
APPENDIX A4: RESIDENTIAL SECTOR (CHAPTER 4)

Table A4.1: Typical flood damages to house structure

House type	Damage component	Expected or actual damages
Brick (floor) Brick (wall) - BB type Av Threshold for damage: height=15cm (st dev = 4) duration=8dys (st dev = 3)	Floor (brick and concrete made) coating,painting	Coating/painting damaged/discoloured: requires replacement; sometimes cracked and foundations damaged: requires repair; damages to mosaic (e.g. resulting from dampness,difficult to be repaired; replacement costs considered.
	Wall (brick made)	Usually cracked, internally or externally, if walls' width=13 cm (5").
	Wall plasters & internal paints	Plasters and paints, especially of skirting damaged; dampness to plasters: require repair/replacements.
	Doors (size 2.2Mx1M) and windows(at 1M height), made of timber	Damage depends on timber quality and duration: Rotting and paints damaged: requires replacement/repainting.
	Roof [rod concrete, and cement (RCC) made; corrugated iron(CI) made]	Roof usually not affected; in exceptional cases when foundations are weak,cracks occur in RCC roofs, and CI roofs lean :requires major repairs.
Brick (floor) C I sheet (wall) - BC type Av Threshold for damage: height=10cm (st dev = 2) duration=7dys (st dev = 3)	Floor (brick and concrete made) coating, painting	As above for BB house type
	Wall (CI sheet made)	Usually rusting occurs depending on duration of water; repair or repainting is enough;if it is old, can totally damage when replacement in full is required.
	CI sheet and wooden frames	Paints on CI sheet and wooden frames damaged; repainting necessary; if timbers are of low quality, prolonged immersion heavily damage when replacement is the only option: saline water in tidal flooding heavily damage CI sheet by erosion:no option short of replacement.
	Doors (size 2.M*1M) and windows (at 1M height)	Damage varies on timber quality,and duration of water: Rotting and paints damaged:requires replacement/repainting.
	Roof [Corrugated iron (CI) made]	Roof not usually affected; in exceptional cases when foundation pilar are week, leans downward: requires major repairs.

Table A4.1 (contd):

House type	Damage component	Expected or actual damages
Mud (floor) C I sheet (wall) - MC type Av Threshold for damage: height=0cm (st dev = 5) duration=4dys (st dev = 2)	Floor (made of earth)	Negligible effects except that some muds are washed and often holes are created: requires labour intensive repair works
	Wall (C I sheet)	As above for BC type houses
	C I sheet, pillars and wooden frames	As above for BC type houses
	Doors (size 2.Mx1M) and windows (at 1M height)	As above for BC type houses
	Roof [mostly Corrugated iron (CI) made,but a few with straw]	As above for BC type houses
Mud (floor) Thatched (wall) - MT type Av Threshold for damage: height= -8cm (st dev = 2) duration=3dys (st dev = 2)	Floor (made of earth)	As above for MC type house
	Wall (Thatched)	Can hardly withstand even moderate velocity water; prolonged water can totally damage, when replacement is required.
	Thatched wall, pillars and wooden frames	Walls and pillars (usually of bamboo) including the thin tar-coating on these are either rotten or washed away; anyway, almost replacement in full is required.
	Doors (size 2.Mx1M) and windows (at 1M height)	Doors can no longer be attached with wall so that these are also almost totally lost.
	Roof [mostly thatched made,but a few with CI sheet]	With walls and pillars being weak, roof can collapse; most often washed away in normal velocity and long duration.

Table A4.1 (contd):

House type	Damage component	Expected or actual damage
Mud (floor) Mud (wall) - MM type Av Threshold for damage: height= -18cm (st dev = 5) duration=1day (st dev = 0)	Floor (made of earth)	As above for MT type house
	Wall (Mud)	Most structures start damages below floor levels; Prolonged immersion (> 3 days) with little above normal velocity help collapse the whole structure, when replacement is required with little scrap value.
	Mud wall, pillars and wooden frames	Mud walls and pillars (usually of bamboo) washed away; anyway, almost replacement in full is required.
	Doors (size 2.Mx1M) and windows (at 1M height)	Doors can no longer be attached with wall so that these are also almost fallen. Paintings and repairs are necessary
	Roof [mostly thatched made, but a few with CI sheet]	With walls and pillars being weak, roof can collapse and washed away in normal velocity and long duration.
'Other houses' (includes outside toilets stores, kitchen livestock shed) Av Threshold for damage: Same as relevant house types	Structure is mostly BB/BC for toilets: roofs mainly of CI sheet; MT for others:roofs mainly of CI sheet.	Often flimsy structure of temporary nature; usually higher susceptibility than the living house

Note: Thresholds averaged over the units in the main case study area. MM type refers to a flash flood in the second case study area.

Table A4.2: Typical flood damages to house contents

Contents group	Susceptibility of items and loss evaluation
Domestic items	Tendency to lift electrical items, eg radio,television, freeze;loss to very few owners;those who could not raise, losses are total; replacement values considered; kitchen utensils and stove etc had losses;many are considered replacement.
Furniture	Most losses occurred to bulky items eg almirah, dinning table, kitchen cabinets, bed; duration has much effects; wooden items were rotten, steel ones rusted; mostly required some cleaning, repairing, repainting;
Personal effects	Ornaments, and especially women clothes had few losses,except some clothes had some strain, which required washing Considerable losses in stock of food,books etc,salvage value of which are marginal.
Installation	Normally little damage to electrical, gas, telephone or water installations; a few metres were reconditioned; considerable damage to safety tanks, water tanks-labour intensive work of cleaning considered; nearly total damage to water pumps.
Transport	Damage to bikes, rickshaw and motor cycles significant-repair costs with replacement of some parts considered;
'other' damages	Mostly livestock moved to safer places; damage to poultry considerable. Kitchen gardens washed in first few days; some fruit trees (e.g. Jack fruit) highly susceptible to even short duration flood.

Thresholds for inventories averaged over units in the main case study area are the following: MM house type refers to a flash flood in the second case study area.

House type	Height (cm)	Duration (days)
BB	18 (st dev = 4)	5 (st dev = 2)
BC	13 (st dev = 3)	6 (st dev = 4)
MC	13 (st dev = 4)	5 (st dev = 4)
MT	10 (st dev = 2)	3 (st dev = 1)
MM	8 (st dev = 2)	3 (st dev = 3)

Table A4.3: Dependent and independent variables used in modelling flood damage

Variable	Definition
Dependent variable	
MHSTDM	Damage to structure to main house (floor, wall, roof and installation)
MHPRDM	Proportional (to value of building) damage to main house
ALSTDM	Damage to structure to all houses including boundary and other houses (eg other houses, kitchen, livestock house etc)
ALSTPRDM	Proportional (to value of building) damage to all house
INVDM	Damage to inventory inside main house
INVPRDM	Proportional (to value) damage to inventory
CLCOST	Cost of clean-up
CLPRCOST	Proportional (to value of building) cost to main house
Independent variables	
DEPTH	Depth of inundation above floor level (in metres)
DUR	Duration of inundation (in days) - a dummy variable: DUR=1 for duration up to 7 days, and DUR=0 for > 7 days
AREA	Floor space of ground floor (in sq metres)
HTYPE	House type - a dummy variable: House types are categorised according to construction of floors and walls, as these are the main damage components of flooding. Eventually, the house type categories have turned out to correspond value and income hierarchies as well. The categorisation of house types are as follows: HTYPE=1: Brick (floor), Brick (wall) -BB HTYPE=2: Brick (floor), Corrugated Iron sheet (CI) wall -BC HTYPE=3: Mud (floor), CI sheet (wall) -MC HTYPE=4: Mud (floor), Thatched (wall) -MT
U_i	Random disturbance in i-th observation
LG	Logarithmic value

Table A4.4: Notes on data generation Tables (Table A4.5 through to A4.12)

For structural damages, no damage-reducing activities are assumed, and so actual damage and potential damages are equal. Damages to inventories, however, are adjusted for damage-reducing measures, through estimating avoided damages by such measures.

The variable DEPTH is measured in metres, DURATION in days; House type (HTYPE) and duration (DUR) are used as categorical variables. Coefficient of determination, R^2s are adjusted for degrees of freedom; N is the number of observation. The models estimated on actual damages are not presented. The presented models used 'potential' damages in actual and hypothetical events.

* Represents significance at 1% level, ** at 5% level and *** at 10% level.

Rounding errors may be cumulative and thus sum total of component damage data may not exactly equal the final damage total. 'all houses' refer to main house and other houses, if any. 'Other houses include, among others, outside kitchen, livestock shed and outside toilets. While constructing potential data set for 'all houses' structures, the damage susceptibility of main house structures have been used as approximations to those to 'other houses'.

Following that floor space of 'other houses' were not available, per square metre damage data are constructed for only main house. Inventory refers to those inside main houses. Clean-up costs have not portrayed any significant relationships with independent variables so that the construction of potential data set for clean-up costs has not been contemplated.

The responses in respect of damage estimates for components such as 'other houses', trees and livestock on hypothetical floods have not been satisfactory so that potential data set construction for these components has not been carried out. However, per household actual damages have been estimated for all these components and clean-up costs in three different floods (See Tables 4.11 through to 13). Livestock include cattle, poultry, and pond fishery.

Approximately Taka 65 = £.

Table A4.5: Regression results for structural damage to main house : Tangail area

MHSTDM = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type Model type	Regression results
Structural :absolute damage to main house -MHDM assumed no damage-reducing activities so actual and potential damages are the same	BB -linear	1997+5045(DEPTH)*+3.70(AREA)*-5413(DUR)* (R^2 = .27 F = 18.6 N =144 P < .00)
	-log log	5.50*+.7877(LGDEPTH)*+.5335(LGAREA)*-.9566(DUR)* (R^2 = .34 F = 25.9 N =144 P < .00)
	BC linear	-1669+6221(DEPTH)* +6.52(AREA)*-3775(DUR)* (R^2 = .32 F = 23.8 N=144 P < .00)
	-log log	4.05*+.9410(LGDEPTH)*+.7705(LGAREA)*-.8124(DUR)* (R^2 = .37 F = 29.5 N=144 P < .00)
	MC -linear	-1257+3898(DEPTH)*+ 7.21(AREA)*-1566(DUR)** (R^2 = .20 F = 11.9 N = 144 P < .00)
	-log log	6.23*+.5917(LGDEPTH)*+.3735(LGAREA)*-.3582(DUR)* (R^2 = .14 F = 8.9 N = 144 P < .00)
	MT -linear	1157*+2037(DEPTH)*+4.68(AREA)*-1336(DUR)* (R^2 = .13 F = 7.8 N = 144 P < .00)
	-log log	5.98*+.4961(LGDEPTH)*+.4063(LGAREA)*-.4241(DUR)* (R^2 = .19 F = 12.4 N = 144 P < .00)
	ALL -linear	-129+4239(DEPTH)*+4.90(AREA)*- 2990(D1)*+927(H1)+780(H2)+375 (H3) (R^2 = .25 F=33.1 N = 576 P < .00)
	-log log	5.54*+.7041(LGDEPTH)*+.5098(LGAREA)*-.6351(D1)*- .0666(H1)-.0060(H2)+.0045(H3) (R^2 = .29 F=39.5 N = 576 P < .00)

Note:
DEPTH measured in metres, DURATION in days and AREA in square metres.
:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576. DUR and HTYPE are dummy variables.
* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.6: Regression results for structural damage to <u>main</u> house : Tangail area

MHPRDM = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type Model type	Regression results
Structural: <u>proportional</u> (to value) damage to main house -MHPRDM	BB -linear	$.0329^{**}+.0449(DEPTH)^{*}-.00001(AREA)$ $-.0399(DUR)^{*}$ (R^2 = .20 F = 12.9 N = 144 P < .00)
	-log log	$-1.98^{*}+.8140(LGDEPTH)^{*}$ $-.1594(LGAREA)-.9461(DUR)^{*}$ (R^2 = .26 F = 17.4 N = 144 P < .00)
	BC -linear	$-.0382^{**}+.0730(DEPTH)^{*}-.00003(AREA)$ $-.0413(DUR)^{*}$ (R^2 = .19 F = 12.1 N = 144 P < .00)
	-log log	$-1.15+.9339(LGDEPTH)^{*}-.2189(LGAREA)^{*}-.8328(DUR)^{*}$ (R^2 = .29 F = 20.7 N = 144 P < .00)
	MC -linear	$.0895^{*}+.0601(DEPTH)^{*}-.0001(AREA)^{*}-.0171(DUR)^{***}$ (R^2 = .16 F = 10.1 N = 144 P < .00)
	-log log	$1.84^{**}+.5622(LGDEPTH)^{*}-.6935(LGAREA)^{*}-.3070(DUR)^{*}$ (R^2 = .19 F = 12.2 N = 144 P < .00)
	MT -linear	$.2711^{*}+.1712(DEPTH)^{*}-.0004(AREA)^{*}-.1164(DUR)^{*}$ (R^2 = .26 F = 17.5 N = 144 P < .00)
	-log log	$1.48^{*}+.5546(LGDEPTH)^{*}-.4869(LGAREA)^{*}-.4519(DUR)^{*}$ (R^2 = .36 F = 27.8 N = 144 P < .00)
	ALL -linear	$.2194^{*}+.0934(DEPTH)^{*}$ $-.00005(AREA)^{*}-.0542(D1)^{*}-.2014(H1)$ $-.1827(H2)-.1635(H3)$ (R^2 =.51 F = 101.4 N= 576 P < .00)
	-log log	$.9474^{**}+.7188(LGDEPTH)^{*}$ $-.3697(LGAREA)^{*}-.6339(D1)^{*}-1.76(H1)$ $-1.28(H2)-.9123(H3)$ (R^2 =.58 F = 134.3 N= 576 P < .00)

Note
DEPTH measured in metres, and DURATION in days and AREA in square metres.
:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576.
DUR and HTYPE are dummy variables.
* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.7: Regression results for damage to <u>all</u> houses : Tangail area

ALSTDM = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type Model type	Regression results
Structural :absolute damage to all house -ALSTDM	BB -linear	2217+6428(DEPTH)*+3.77(AREA)*-.6423(DUR)* (R^2 = .30 F = 21.8 N = 144 P < .00)
	-log log	5.37+.8300(LGDEPTH)*+.5869(LGAREA)*-.9448(DUR)* (R^2 = .35 F = 26.9 N = 144 P < .00)
	BC -linear	-4103***+8936(DEPTH)*+12.55(AREA)*-5072(DUR)* (R^2 = .27 F = 18.9 N = 144 P < .00)
	-log log	4.23*+.9020(LGDEPTH)*+.7908(LGAREA)*-.8096(DUR)* (R^2 = .32 F = 23.6 N = 144 P < .00)
	MC -linear	-940+4803(DEPTH)*+7.37(AREA)*-1835(DUR)* (R^2 = .18 F = 11.3 N = 144 P < .00)
	-log log	6.75*+.5999(LGDEPTH)*+.3191(LGAREA)*-.3456(DUR)* (R^2 = .12 F = 7.3 N = 144 P < .00)
	MT -linear	371+2066(DEPTH)*+9.70(AREA)*-1578(DUR)* (R^2 = .20 F = 13.0 N = 144 P < .00)
	-log log	5.65*+.4836(LGDEPTH)*+.4852(LGAREA)*-.4275(DUR)* (R^2 = .20 F = 12.5 N = 144 P < .00)
	ALL -linear	-839+5420(DEPTH)*+6.58(AREA)* - 3657(D1)*+843(H1)+2704(H2)*+590(H3) (R^2 =.26 F=35.1 N =576 P < .00)
	-log log	5.46*+.7041(LGDEPTH)*+.5428(LGAREA)*-.6298(D1)*- .0354(H1)+.2073(H2)***+.0697(H3) (R^2 =.29 F=40.8 N =576 P < .00)

Note

DEPTH measured in metres, and DURATION in days.

:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576.DUR and HTYPE are dummy variables.

:* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.8: Regression results for damage to all houses : Tangail area

ALSTPRDM = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type Model type	Regression results
Structural: proportional (to value) damage to all house -ALSTPRDM	BB -linear	.0350**+.0541(DEPTH)*-.00001(AREA)-.0464(DUR)* (R^2 = .23 F = 15.5 N = 144 P < .00)
	-log log	-2.17**+.8536(LGDEPTH)* -.1055(LGAREA)-.9335(DUR)* (R^2 = .25 F = 17.1 N = 144 P < .00)
	BC -linear	.0505**+.0838(DEPTH)* -.00003(AREA)-.0496(DUR)* (R^2 = .20 F = 13.0 N = 144 P < .00)
	-log log	-.9894**+.8536(LGDEPTH)* -.1055(LGAREA)-.9355(DUR)* (R^2 = .29 F = 20.5 N = 144 P < .00)
	MC -linear	.1066*+.0750(DEPTH)* -.0001(AREA)* -.0213(DUR)** (R^2 = .19 F = 12.0 N = 144 P < .00)
	-log log	1.56**+.5440(LGDEPTH)* -.4940(LGAREA)* -.4549(DUR)** (R^2 = .20 F = 12.8 N = 144 P < .00)
	MT -linear	.2814*+.1676(DEPTH)*-.0004(AREA)*-.1204(DUR)* (R^2 = .25 F = 17.0 N = 144 P < .00)
	-log log	1.55*+.5440(LGDEPTH)*-.4940(LGAREA)*-.4540(DUR)* (R^2 = .37 F = 28.9 N = 144 P < .00)
	ALL -linear	.2259*+.1006(DEPTH)* -.00005(AREA)*-.0596(D1)*-.2030(H1)* -.1731(H2)*-.1564(H3)* (R^2 =.50 F =96.3 N =576 P < .00)
	-log log	.9324**+.7157(LGDEPTH)* -.3602(LGAREA)*-.6275(D1)*-1.66(H1)* -1.05(H2)*-.7980(H3)* (R^2 =.55 F =118.5 N =576 P < .00)

Note
DEPTH measured in metres, and DURATION in days.
:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576.
:* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.9: Regression results for damage to inventories: Tangail area

INVDM = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type Model type	Regression results
Inventory :absolute damage to main house -INVDM	BB -linear	$1827^{*}+25649(DEPTH)^{*}$ $-6.97(AREA)^{**}-18416(DUR)^{*}$ $(R^2 =.19\ \ F=12.1\ \ N =144\ P <00)$
	-log log	$11.08^{*}+.7927(LGDEPTH)^{*}-.1092(LGAREA)-.7186(DUR)^{*}$ $(R^2 = .30\ F = 21.9\ \ N = 144\ P < .00)$
	BC -linear	$2241+20424(DEPTH)^{*}+10.13(AREA)^{*}-1166(DUR)^{*}$ $(R^2 = .26\ F = 17.8\ \ N = 144\ P < .00)$
	-log log	$8.16^{*}+.9586(LGDEPTH)^{*}+.3191(LGAREA)^{*}-.6652(DUR)^{*}$ $(R^2 = .32\ F = 23.2\ \ N = 144\ P < .00)$
	MC -linear	$9.94+8373(DEPTH)^{*}+14.13(AREA)^{*}-3421(DUR)^{**}$ $(R^2 = .14\ F = 8.6\ \ N = 144\ P < .00)$
	-log log	$5.60^{*}+.5084(LGDEPTH)^{*}+.6145(LGAREA)^{*}-.2786(DUR)^{*}$ $(R^2 = .12\ F = 7.2\ \ N = 144\ P < .00)$
	MT -linear	$416+4518(DEPTH)^{**}+13.08(AREA)^{*}-2277(DUR)^{*}$ $(R^2 = .09\ F = 5.6\ \ N = 144\ P < .00)$
	-log log	$2.57^{**}+.5192(LGDEPTH)^{***}+1.08(LGAREA)^{*}-.2822(DUR)$ $(R^2 = .20\ F = 12.8\ \ N = 144\ P < .00)$
	ALL -linear	$-1884+14542(DEPTH)^{*}+.8258(AREA)$ $-8983(DUR)^{*}+20607(H1)^{*}+13622(H2)^{*}$ $+5900(H3)^{*}$ $(R^2 = .29\ \ F=39.7\ \ N = 576\ P < .00)$
	-log log	$6.20^{*}+.6941(LGDEPTH)^{*}+.4416(LGAREA)^{*}$ $-.4859(DUR)^{*}+1.27(H1)^{*}+1.04(H2)^{*}$ $+.5958(H3)^{*}$ $(R^2 = .43\ F = 72.5\ \ N = 576\ P < .00)$

Note
:DEPTH measured in metres, and DURATION in days.
:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576.
:* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.10: Regression results for damage to inventories: Tangail area

INVPRDM = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type Model type	Regression results
Inventory: proportional (to value) damage to inventories inside main house -INVPRDM	BB -linear	$.1886^{*}+.2216(\text{DEPTH})^{*}$ $-.0001(\text{AREA})^{*}-.1550(\text{DUR})^{*}$ $(R^2 = .33 \quad F = 25.3 \quad N = 144 \quad P < .00)$
	-log log	$1.91^{*}+.8439(\text{LGDEPTH})^{*}$ $-.5019(\text{LGAREA})^{*}-.7462(\text{DUR})^{*}$ $(R^2 = .50 \quad F = 48.7 \quad N = 144 \quad P < 00)$
	BC -linear	$.0893^{**}+.2834(\text{DEPTH})^{*}-.0001(\text{AREA})^{*}-.1343(\text{DUR})^{*}$ $(R^2 = .37 \quad F = 29.3 \quad N = 144 \quad P < .00)$
	-log log	$.6745+1.03(\text{LGDEPTH})^{*}-.2905(\text{LGAREA})^{*}-.6996(\text{DUR})^{*}$ $(R^2 = .44 \quad F = 38.0 \quad N = 144 \quad P < .00)$
	MC -linear	$.2199^{*}+.1424(\text{DEPTH})^{*}-.0002(\text{AREA})^{*}-.0625(\text{DUR})^{*}$ $(R^2 = .34 \quad F = 25.5 \quad N = 144 \quad P < .00)$
	-log log	$1.83^{*}+.6200(\text{LGDEPTH})^{*}-.5348(\text{LGAREA})^{*}-.3314(\text{DUR})^{*}$ $(R^2 = .38 \quad F = 30.8 \quad N = 144 \quad P < .00)$
	MT -linear	$-.1821^{*}+.2195(\text{DEPTH})^{*}-.0001(\text{AREA})-.0836(\text{DUR})^{*}$ $(R^2 = .21 \quad F = 14.1 \quad N = 144 \quad P < .00)$
	-log log	$-.6789^{***}+.6259(\text{LGDEPTH})^{*}-.0654(\text{LGAREA})-.2494(\text{DUR})^{*}$ $(R^2 = .29 \quad F = 20.1 \quad N = 144 \quad P < .00)$
	ALL -linear	$.2088^{*}+.2160(\text{DEPTH})^{*}$ $-.00013(\text{AREA})^{*}-.1084(\text{D1})^{*}-.0400(\text{H1})^{**}-.0345(\text{H2})^{**}-.0768(\text{H3})^{*}$ $(R^2 = .34 \quad F = 50.3 \quad N = 576 \quad P < .00)$
	-log log	$1.03^{*}+.7784(\text{LGDEPTH})^{*}$ $-.3487(\text{LGAREA})^{*}-.5034(\text{D1})^{*}-.2143(\text{H1})^{*}-.1315(\text{H2})^{***}-.2290(\text{H3})^{*}$ $(R^2 = .44 \quad F = 75.4 \quad N = 576 \quad P < 00)$

Note
:DEPTH measured in metres, and DURATION in days.
:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576.
:* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.11: Regression results for clean-up cost : Tangail area

CLCOST = f (DEPTH, AREA, DUR, HTYPE)

Dependent variable	House type	Regression results
Clean-up cost: absolute cost CLCOST	BB -log log	$3.98^{*}+.1361(LGDEPTH)+.3230(LGAREA)^{*}$ $-.1142(DUR)^{*}$ (R^2 =.04 F=2.8 N =144 P < .05)
	BC -log log	$2.66^{*}-.0993(LGDEPTH)+.5050(LGAREA)^{*}$ $-.0114(DUR)$ (R^2 = .06 F = 4.4 N = 144 P < .00)
	MC -log log	$4.04^{*}+.0431(LGDEPTH)-.2720(LGAREA)^{***}$ $-.0410(DUR)$ (R^2 = -.0005 F =.97 N =144 P < .41)
	MT -log log	$2.52^{*}+.1535(LGDEPTH)+.4659(LGAREA)^{*}$ $-.0278(DUR)$ (R^2 = .13 F = 7.9 N = 144 P < .00)
	ALL -log log	$2.95^{*}+.0621(LGDEPTH)+.3880(LGAREA)^{*}-$ $.0510(DUR)+.5711(H1)^{*}+.5023(H2)^{*}+.3732(H3)^{*}$ (R^2 =.24 F=31.2 N =576 P < .00)

:DEPTH measured in metres, and DURATION in days.
:Coefficient of determination, R^2 are adjusted for degrees of freedom; total sample size is 576.
:* Represents significant at 1% level, ** at 5% level and *** at 10% level.

Table A4.12: Regression results for clean-up cost : Tangail area

CLPRCOST = f (DEPTH, AREA, DUR, HTYPE)

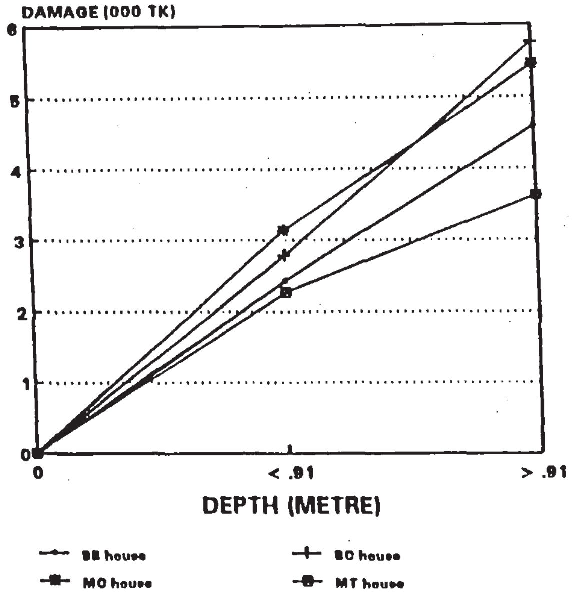
Dependent variable	House type Model type	Regression results
Clean-up cost: Proportional (to value) cost -CLPRCOST	BB -linear	.0036*+.0002(DEPTH)-.00004(AREA) -.0003(DUR) (R^{2} =-.01 F=.39 N = 144 P < .76)
	-log log	-5.97*+.1127(LGDEPTH)+.070(LGAREA) -.1273(DUR) (R^{2} =-.01 F=.51 N = 144 P < .67)
	BC -linear	.0042*-.00005(DEPTH)+.0004(AREA) +.00006(DUR) (R^{2} =-.02 F = .20 N = 144 P < .90)
	-log log	-5.60*-.0059(LGDEPTH)+.0039(LGAREA) +.0416(DUR) (R^{2} =-.02 F = .03 N = 144 P < .99)
	MC -linear	0142*+.0002(DEPTH)-.0027(AREA)*** -.0002(DUR) (R^{2} = .01 F =1.3 N =144 P < .27)
	-log log	-4.69*+.0511(LGDEPTH)-.7670(LGAREA)** -.0110(DUR) (R^{2} = .05 F =3.3 N =144 P < .02)
	MT -linear	.0189*+.0002(DEPTH)-.0026(AREA)*** -.00003(DUR) (R^{2} = .004 F = .97 N = 144 P < .41)
	-log log	-4.35*+.0567(LGDEPTH)-.2903(LGAREA)*** -.0048(DUR) (R^{2} = .004 F = 1.2 N = 144 P < .31)
	ALL -linear	.0169*+.0002(DEPTH)-.0011(AREA)**-.00005(DUR)-.0107(H1)*- .0094(H2)*-.0060(H3)* (R^{2} =.25 F=32.7 N =576 P < .00)
	-log log	-4.36*+.0595(LGDEPTH)-.2305(LGAREA)**-.0213(DUR)- 1.39(H1)*-1.05(H2)*+.7384(H3)* (R^{2} =.30 F=42.5 N =576 P < .00)

:DEPTH measured in metres, and DURATION in days.
:Coefficient of determination, R^{2} are adjusted for degrees of freedom; total sample size is 576.
:* Represents significant at 1% level, ** at 5% level and *** at 10% level.

DEPTH-DAMAGE CURVES : RESIDENTIAL SECTOR

FIG A4.1: DEPTH DAMAGE CURVE

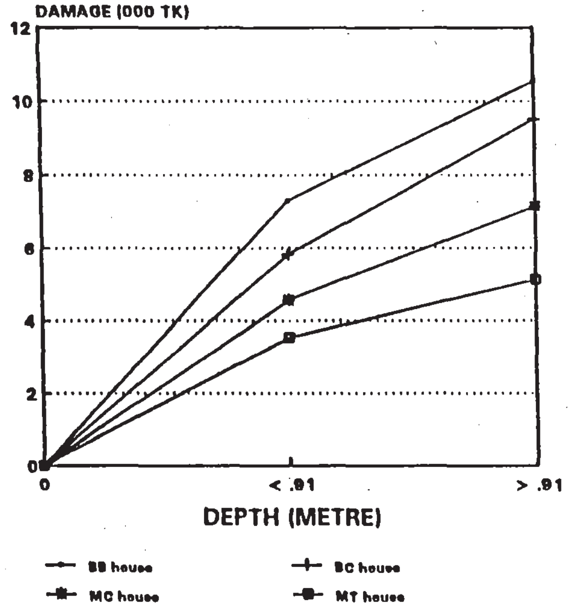
STRUCTURAL DAMAGE TO MAIN HOUSE:TANGAIL



DURATION UP TO 7 DAYS

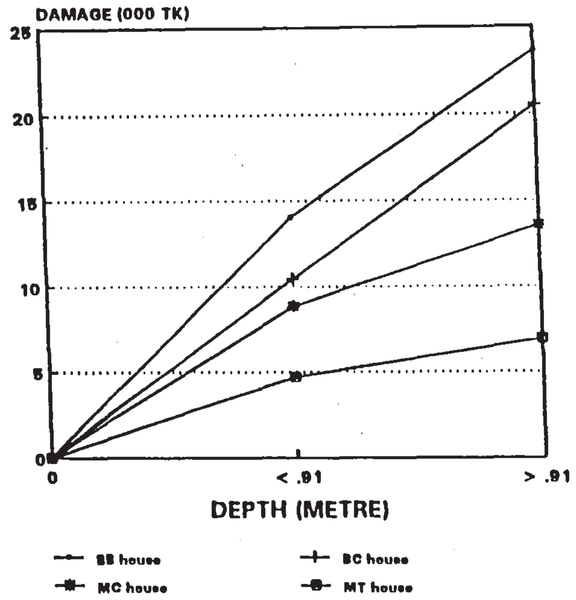
FIG A4.2: DEPTH DAMAGE CURVE

STRUCTURAL DAMAGE TO MAIN HOUSE:TANGAIL



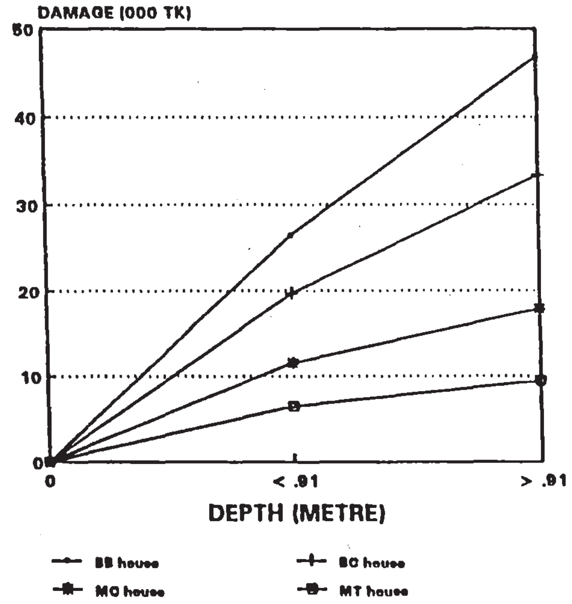
DURATION > 7 DAYS

FIG A4.3: DEPTH DAMAGE CURVE
INVENTORIES DAMAGE IN MAIN HOUSE:TANGAIL



DURATION UP TO 7 DAYS

FIG A4.4: DEPTH DAMAGE CURVE
INVENTORIES DAMAGE IN MAIN HOUSE:TANGAIL



DURATION > 7 DAYS

Table A4.13: Associations of selected dependent variables with house type

[X2 = Chi squared value, M-H Test = Mantel-Haenszel Test of linear association, S=Significant at 95% level, NS = Not significant,
- = Observations insufficient or not available]

DEPENDENT VARIABLE	X2 value			Linear Association (M-H Test)		
	FLOOD TYPE			FLOOD TYPE		
	1	2	3	1	2	3
LENGTH OF INTERNAL WALL	S	S	NS	S	S	S
AGE OF BUILDING	NS	NS	NS	NS	NS	NS
EXTERNAL CONDITION	S	S	S	S	S	S
YEARS OF LIVING	NS	S	NS	NS	NS	NS
AREA OF GROUND FLOOR	S	S	S	S	S	S
AREA OF OPEN SPACE	S	NS	NS	S	NS	NS
AREA OF CEILING SPACE	S	NS	S	S	S	S
AREA OF TOTAL SPACE	S	S	S	S	S	S
VALUE OF G FLOOR	S	S	S	S	S	S
FREQUENCY OF FLOODING	NS	S	S	S	S	S
DEPTH OF FLOODING	S	S	S	S	NS	S
DURATION OF FLOODING	NS	S	NS	NS	S	NS
FLOOR HEIGHT	NS	NS	S	S	NS	S
THRESHOLD HEIGHT-STRUCTURE	S	S	S	S	S	S
THRESHOLD HEIGHT-INVENTORIES	S	S	NS	S	S	NS
THRESHOLD DURATION-STRUCTURE	S	S	S	S	S	S
THRESHOLD DURATION-INVENTORIES	NS	S	NS	NS	NS	NS
DAMAGE TO FLOOR	S	NS	S	S	NS	NS
DAMAGE TO WALL	NS	S	NS	NS	S	NS
DAMAGE TO ROOF	-	S	S	-	S	S
TOTAL STRUCT DAMAGE TO MAIN HOUSE	S	S	NS	S	S	S
TOTAL STRUCT DAMAGE TO ALL HOUSES	S	S	S	S	S	S
TYPE OF SUBSEQUENT DAMAGE	S	S	S	S	S	S
% STRUCTURAL DAMAGE REPAIRED YOURSELF	S	S	S	S	S	S
% STRUCT DAMAGE REPAIRED BY HIRED WORKER	S	S	S	S	S	S
% STRUCTURAL DAMAGE RECOVERED	S	NS	NS	S	NS	NS
TOTAL TIME TO RECOVER	NS	S	NS	S	S	S
DAYS TAKEN FOR CLEAN-UP	NS	S	NS	S	NS	S
PERSON DAYS BY FAMILY ON CLEAN-UP	S	S	NS	S	S	NS
PERSON DAYS BY HIRED WKS ON CLEAN-UP	S	S	S	S	S	S

Table A4.13 (contd) :

TOTAL PERSON DAYS ON CLEAN-UP	S	NS	NS	S	NS	S
TOTAL COST OF CLEAN-UP	S	S	S	S	NS	S
VALUE OF INVENTORIES	S	S	S	S	S	S
DAMAGE TO INVENTORIES	S	S	S	S	S	S
IF ANY IRREPARABLE DAMAGE CAUSED	NS	S	S	NS	NS	S
NUMBER OF MEMBERS HEALTH AFFECTED	NS	S	NS	NS	S	NS
MONTHLY MEDICAL EXPENSES	S	-	S	S	-	S
EFFECT ON ADDITIONAL MEDICAL EXPENSES	NS	-	NS	NS	-	NS
USED TO FLOODS, HARDLY WORRY	NS	-	NS	NS	-	NS
WORRIED WHEN RAINS HEAVILY	NS	-	NS	NS	-	NS
WORRIED IF NEIGHBOURING AREAS FLOODED	NS	-	NS	NS	-	NS
KEEP STOCK OF FOOD ETC ON APPREHENSION	NS	-	NS	NS	-	NS
NOTHING CAN BE DONE, MUST LIVE WITH FLOOD	NS	-	S	NS	-	NS
VALUE OF TREES	S	NS	S	S	S	S
DAMAGE TO TREES	NS	NS	NS	NS	NS	NS
TOTAL VALUE LIVESTOCK	NS	S	NS	NS	S	NS
DAMAGE TO LIVESTOCK	S	S	S	S	S	S
VALUE OF OTHER HOUSES	NS	S	S	NS	S	S
DAMAGE TO OTHER HOUSES	S	S	NS	S	S	NS
TOTAL VALUE OF 'ALL OTHER' ASSETS	S	S	S	S	S	S
TOTAL DAMAGE TO 'ALL OTHER' ASSETS	NS	S	S	NS	S	S
IF BELIEVED MESSAGE OF WARNING	NA	S	NS	NA	S	NS
LEAD TIME BEFORE WATER ENTERED	NA	S	S	NA	S	S
IF PERCEIVED FLOODING GOING TO OCCUR	-	S	-	-	S	-
PERCEIVED HOURS BEFORE FLOOD ENTERED	NS	S	-	NS	S	-
HRS BETWEEN WATER ENTERED TOWN AND PROPERTY	S	S	-	S	S	-
% VALUE OF CONTENTS AT RISK	S	S	S	S	S	S
% VALUE OF RISKY CONTENTS MOVED	S	S	-	S	S	-
VALUE OF DAMAGES AVOIDED BY REMOVAL	S	S	-	S	S	-
IF HAD ANY SUBSIDIARY OCCUPATION	NS	NS	NS	NS	NS	NS
NUMBER OF MEMBERS IN HOUSEHOLD	NS	S	NS	NS	S	NS
NUMBER OF MEMBERS EARNING	S	NS	NS	S	NS	NS
INCOME OF HOUSEHOLD FROM ALL SOURCES	S	S	S	S	S	S
EMPLOYMENT IMPACT ON HOUSEHOLD	NS	S	NS	NS	S	NS
INCOME IMPACT ON HOUSEHOLD	S	S	NS	S	S	NS
% OF TOTAL MONTHLY INCOME LOST	S	S	NS	NS	S	NS

Table A4.13 (contd) :

IF TRADERS CREATED SHORTAGE OF NECESSITIES	NS	-	NS	NS	-	NS
IF ANY MEMBER DID EVACUATE	S	S	-	S	S	-
WHO MOVED TO SAFER PLACE	S	S	-	S	S	-
DAYS OF STAYING OUTSIDE	NS	S	S	S	S	S
IF HELPED ANYONE WITH EVACUATION ETC	S	NS	NS	S	S	NS
STATE OF COMMUNITY SPIRIT	NS	S	NS	NS	S	NS
IF RECEIVED ANY HELP FROM OTHERS	S	S	S	S	S	S
IF UPPER FLOOR RESIDENTS HELPED	NS	S	NS	NS	S	NS
ROLE OF AFFLUENT SECTIONS	NS	NS	NS	NS	S	NS
% DAMAGE TO STRUCTURE DUE TO VELOCITY	NA	S	NS	NA	S	NS
% DAMAGE TO INVENTORY DUE TO VELOCITY	NA	S	NS	NA	S	NS
% DAMAGE TO OTHERS DUE TO VELOCITY	NA	NS	NS	NA	NS	NS
% DAMAGE TO STRUCTURE DUE TO STORM	NA	NA	NS	NA	NA	NS
% DAMAGE TO INVENTORY DUE TO STORM	NA	NA	S	NA	NA	S
% DAMAGE TO OTHERS DUE TO STORM	NA	NA	NS	NA	NA	S
% DAMAGE TO STRUCTURE DUE TO SALT	NA	NA	NS	NA	NA	NS
% DAMAGE TO INVENTORY DUE TO SALT	NA	NA	S	NA	NA	S
% DAMAGE TO OTHERS DUE TO SALT	NA	NA	NS	NA	NA	NS
POTENTIAL INVENTORY DAMAGE(ACTUAL+ AVOIDED)	S	S	S	S	S	S
DAMAGE AVOIDED AS % OF POTENTIAL DAMAGE	S	S	-	S	S	-
DAMAGE AVOIDED AS % OF VALUE OF INVENTORY	NS	NS	-	NS	NS	-
STRUCTURAL DAMAGE AS % OF VALUE OF BUILDING	S	S	S	S	S	S
ACTUAL INVENTORY DAMAGE AS % OF VALUE	S	S	S	S	S	S
POTENTIAL INVENTORY DAMAGE AS % OF VALUE	S	S	S	S	S	S
DAMAGE TO 'OTHER ASSETS' AS % OF VALUE	NS	S	NS	S	S	NS

Table A4.14: Labels of selected variables under study of association

Dependent variable	Label	Independent Variable	Label
TOTMHDAM	STRUCTURAL DAMAGE TO MAIN HOUSE	AGE	AGE OF PROPERTY
TOTSTDAM	TOTAL DAMAGE TO ALL STRUCTURES	COND	CONDITION OF PROPERTY
TOTDAM	ACTUAL DAMAGE TO INVENTORIES (IN MAIN HOUSE)	INTER	LENGTH OF INTERNAL WALLS
DAMAVOD	DAMAGE (TO INVENTORIES) AVOIDED BY ANY MEASURES	AREAC	AREA OF CEILING UNDER ROOF
POTDAM	POTENTIAL DAMAGE TO INVENTORIES (TOTDAM + DAMAVOD)	AREAG	AREA OF GROUND FLOOR
PROPMV	PROPORTION OF EXPOSED (TO FLOOD)CONTENTS MOVED	FREQ	FREQUENCY OF FLOODING
DAMAVOD1	DAMAGE AVOIDED (DAMAVOD)AS % OF POTENTIAL DAMAGE(POTDAM)	BLIEV	IF BELIEVED MESSAGE OF WARNING GIVEN
DAMAVOD2	DAMAVOD AS % OF TOTAL VALUE OF INVENTORIES	LEAD	TIME BETW WARNING & WATER ENTERED IN PROPERTY
DAMPROP1	STRUCTURAL DAMAGE AS % OF VALUE OF BUILDING	PRLED	TIME BETW PERCEIVED (ASCERTAINING THAT FLOOD GOING TO HAPPEN) AND WATER ENTERED
DAMPROP2	TOTDAM AS % OF VALUE OF INVENTORIES	ENTER	TIME BETWEEN WATER ENTERED TOWN & PROPERTY
DAMPROP3	POTDAM AS % OF VALUE OF INVENTORIES	WARD	CATEGORICAL VARIABLE - WARD'S NAME
DAMPROP4	DAMAGE TO 'OTHER' ASSETS AS % OF VALUE	YRS	YEARS OF LIVING IN PROPERTY
DUR	DURATION OF FLOODING	DEPTH	DEPTH OF FLOODING
INCMLOST	% OF MONTHLY INCOME LOST	DUR	DURATION OF FLOODING
MOVE	VALUE OF INVENTORIES MOVED/RAISED TO SAFER PLACE	VALGF	VALUE OF GROUND FLOOR BUILDING
		INVAL	VALUE OF INVENTORIES
		RSKPR	% OF INVENTORIES AT RISK
		ADULT	NUMBER OF ADULT MEMBERS IN HOUSEHOLD
		COMTY	COMMUNITY SPIRIT DURING FLOOD
		ROLE	ROLE OF AFFLUENT COMMUNITY DURING FLOOD

Table A4.15: Associations among selected dependent and independent variables
[X2 = CHI SQUARED VALUE; LA = TEST FOR LINEAR ASSOCIATION (Mantel-Haenszel Test); S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT; NA=NOT APPLICABLE;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]
Flood type : Major river flood

Dependent variable	Association with independent variables																			
	AGE		COND		INTER		AREAC		AREAG		FREQ		BLIEV		LEAD		PRLED		ENTER	
	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA
TOTMHDAM	NS	NS	NS	NS	S	S	-	-	S	S	NS	NS	-	-	-	-	NS	NS	S	S
TOTSTDAM	NS	NS	S	S	-	-	-	-	S	S	NS	NS	-	-	-	-	NS	NS	NS	NS
TOTDAM	-	-	-	S	-	-	NS	NS	S	S	NS	NS	-	-	-	-	NS	NS	NS	NS
DAMAVOD	-	-	-	-	-	-	S	S	S	S	NS	NS	-	-	-	-	NS	NS	S	S
POTDAM	-	-	-	-	-	-	S	S	S	S	NS	NS	-	-	-	-	NS	NS	S	S
PROPMV	-	-	-	-	-	-	S	S	-	-	S	S	-	-	-	-	NS	NS	S	S
DAMAVOD1	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	-	-	-	-	NS	NS	NS	S
DAMAVOD2	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	-	-	-	-	NS	NS	S	S
DAMPROP1	NS	NS	S	S	S	S	-	-	S	S	NS	S	-	-	-	-	NS	NS	S	NS
DAMPROP2	NS	NS	-	-	-	-	S	S	S	S	NS	S	-	-	-	-	NS	NS	S	NS
DAMPROP3	NS	NS	-	-	-	-	S	S	S	S	NS	S	-	-	-	-	NS	NS	NS	NS
DAMPROP4	NS	NS	-	-	-	-	NS	NS	-	-	NS	NS	-	-	-	-	NS	NS	NS	NS
DEPTH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INCMLOST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	WARD		YRS		DEPTH		DUR		VALGF		INVAL		RSKPR		ADULT		COMTY		ROLE	
	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA
TOTMHDAM	NS	NS	NS	NS	NS	NS	S	NS	S	S	-	-	-	-	NS	NS	NS	NS	NS	NS
TOTSTDAM	NS	NS	NS	NS	NS	NS	NS	S	S	S	-	-	-	-	NS	NS	NS	NS	NS	NS
TOTDAM	NS	NS	NS	NS	S	NS	NS	NS	S	S	S	S	NS	NS	NS	S	S	S	NS	S
DAMAVOD	NS	NS	NS	NS	NS	NS	NS	NS	-	-	S	S	NS	NS	NS	S	S	S	S	S
POTDAM	NS	NS	NS	NS	S	S	NS	NS	S	S	S	S	NS	NS	NS	S	S	S	S	S
PROPMV	S	NS	NS	NS	NS	NS	NS	NS	-	-	S	S	NS	NS	NS	NS	NS	NS	NS	NS
DAMAVOD1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DAMAVOD2	S	NS	NS	NS	NS	NS	NS	NS	S	S	S	S	S	S	NS	S	NS	S	NS	NS
DAMPROP1	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	S	S	NS	NS	NS	NS
DAMPROP2	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	NS	NS	NS	NS	NS	NS
DAMPROP3	S	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	NS	NS	NS	NS	NS	NS
DAMPROP4	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	S	S	NS	NS
DEPTH	S	S	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-
DUR	S	NS	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INCMLOST	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-	-	-	S	S	-	-	-	-

Note:For definition of variables, see Table A4.14.

Table A4.16: Associations among selected dependent and independent variables
[X2 = CHI SQUARED VALUE; LA = TEST FOR LINEAR ASSOCIATION (Mantel-Haenszel Test); S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]
Flood type : Flash flood

Dependent variable	Association with independent variables																			
	AGE		COND		INTER		AREAC		AREAG		FREQ		BLIEV		LEAD		PRLED		ENTER	
	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA
TOTMHDAM	NS	NS	S	S	S	S	-	-	S	S	S	S	NS	NS	NS	NS	NS	NS	S	S
TOTSTDAM	NS	NS	NS	NS	-	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	S	S	NS	NS
TOTDAM	-	-	-	-	-	-	S	S	S	S	NS	NS	S	S	NS	NS	S	S	NS	NS
DAMAVOD	-	-	-	-	-	-	NS	NS	NS	S	NS	NS	S	S	NS	S	S	S	NS	S
POTDAM	-	-	-	-	-	-	S	S	S	S	NS	NS	S	S	NS	S	S	S	NS	S
PROPMV	-	-	-	-	-	-	NS	NS	-	-	NS	NS	S	S	NS	NS	S	S	NS	NS
DAMAVOD1	-	-	-	-	-	-	NS	NS	S	S	NS	NS	S	S	NS	NS	NS	NS	NS	NS
DAMAVOD2	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	S	S	NS	NS	S	S	NS	NS
DAMPROP1	NS	NS	S	S	S	S	-	-	S	S	S	NS	S	S	S	S	NS	NS	S	S
DAMPROP2	NS	NS	-	-	-	-	NS	NS	S	S	NS	NS	NS	NS	NS	NS	NS	NS	S	S
DAMPROP3	NS	NS	-	-	-	-	NS	NS	S	S	S	NS	NS	NS	NS	NS	S	S	NS	S
DAMPROP4	NS	NS	-	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DEPTH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INCMLOST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	WARD		YRS		DEPTH		DUR		VALGF		INVAL		RSKPR		ADULT		COMTY		ROLE	
	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA
TOTMHDAM	-	-	NS	NS	NS	NS	S	S	S	S	-	-	-	-	NS	NS	S	S	NS	NS
TOTSTDAM	-	-	NS	NS	S	S	S	S	S	S	-	-	-	-	NS	NS	NS	NS	S	S
TOTDAM	-	-	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	S	S	S	S
DAMAVOD	-	-	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	S	S	NS	NS
POTDAM	-	-	NS	NS	NS	NS	NS	NS	S	S	S	S	S	S	S	S	NS	NS	NS	NS
PROPMV	-	-	NS	NS	NS	NS	NS	S	-	-	S	S	S	S	S	S	S	S	NS	NS
DAMAVOD1	-	-	NS	NS	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	NS	NS
DAMAVOD2	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	NS	NS	NS	NS	NS	NS
DAMPROP1	-	-	NS	NS	NS	NS	S	S	S	S	-	-	S	S	S	S	S	S	NS	S
DAMPROP2	-	-	NS	NS	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	NS	NS
DAMPROP3	-	-	NS	NS	S	NS	S	S	S	S	S	S	S	S	NS	NS	S	S	NS	NS
DAMPROP4	-	-	NS	NS	NS	NS	NS	NS	S	S	NS	NS	S	S	NS	NS	NS	NS	NS	NS
DEPTH	-	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-
DUR	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INCMLOST	-	-	NS	NS	NS	NS	S	S	-	-	-	-	-	-	S	S	-	-	-	-

Note:For definition of variables, see Table A4.14.

Table A4.17: Associations among selected dependent and independent variables
[X2 = CHI SQUARED VALUE; LA = TEST FOR LINEAR ASSOCIATION (Mantel-Haenszel Test); S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]
Flood type : Tidal flood

Dependent variable	Association with independent variables																			
	AGE		COND		INTER		AREAC		AREAG		FREQ		BLIEV		LEAD		PRLED		ENTER	
	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA
TOTMHDAM	NS	NS	S	S	S	S	-	-	S	S	NS	NS	-	-	NS	NS	-	-	-	-
TOTSTDAM	NS	NS	NS	NS	-	-	-	-	S	S	NS	NS	-	-	NS	NS	-	-	-	-
TOTDAM	-	-	-	-	-	-	NS	NS	S	S	NS	NS	-	-	NS	NS	-	-	-	-
DAMAVOD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
POTDAM	-	-	-	-	-	-	S	S	S	S	NS	NS	-	-	NS	NS	-	-	-	-
PROPMV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DAMAVOD1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DAMAVOD2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DAMPROP1	NS	NS	S	S	S	S	-	-	S	S	S	S	-	-	NS	NS	-	-	-	-
DAMPROP2	NS	S	-	-	-	-	NS	NS	NS	S	S	S	-	-	NS	NS	-	-	-	-
DAMPROP3	NS	S	-	-	-	-	NS	NS	NS	S	S	S	-	-	NS	NS	-	-	-	-
DAMPROP4	NS	NS	-	-	-	-	NS	NS	NS	S	NS	S	-	-	NS	NS	-	-	-	-
DEPTH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INCMLOST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WARD		YRS		DEPTH		DUR		VALGF		INVAL		RSKPR		ADULT		COMTY		ROLE	
	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA	X2	LA
TOTMHDAM	-	-	NS	NS	NS	NS	NS	NS	S	S	-	-	-	-	NS	NS	NS	NS	NS	NS
TOTSTDAM	-	-	NS	NS	NS	NS	NS	NS	S	S	-	-	-	-	NS	NS	NS	NS	NS	NS
TOTDAM	-	-	NS	NS	NS	NS	NS	NS	S	S	S	S	NS	NS	NS	NS	NS	NS	NS	NS
DAMAVOD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
POTDAM	-	-	NS	NS	NS	S	NS	NS	S	S	S	S	NS	NS	NS	NS	NS	NS	NS	NS
PROPMV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DAMAVOD1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DAMAVOD2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DAMPROP1	-	-	NS	NS	S	S	NS	NS	S	S	-	-	-	-	S	S	NS	S	S	S
DAMPROP2	-	-	NS	S	S	S	S	S	S	S	S	S	S	S	NS	NS	S	S	S	S
DAMPROP3	-	-	NS	S	S	S	S	S	S	S	S	S	S	S	NS	S	S	S	S	S
DAMPROP4	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS
DEPTH	-	-	-	-	-	-	NS	NS	-	-	-	-	-	-	-	-	-	-	-	-
DUR	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INCMLOST	-	-	NS	NS	NS	NS	NS	NS	-	-	-	-	-	-	S	S	-	-	-	-

Note:For definition of variables, see Table A4.14.

Table A4.18: Correlations of selected key-variables

Flood type : Major river flood

Correlations	VALGF	INVAL	INTER	AREAC	AREAG	COND
TOTMHDM	.53*	-	.28*	-	.53*	.08
TOTSTDM	.63*	-	.26*	-	.58*	.13
TOTDAM	.39*	.67*	-	.20	.31*	-
DAMAVOD	-	.81*	-	.36*	.41*	-
DAMPROP1	-.50*	-	-.28*	-	-.49*	-.40*
DAMPROP2	-	-.38*	-	-.25*	-.31*	-
DAMPROP3	-	-.46*	-	-.22*	-.39*	-
DAMPROP4	-	-	-	-	-	-
MOVE	-	.87*	-	.38*	.52*	-
DAMAVOD1	-	.16	-	.19	.11	-

Correlations:	DEPTH	DUR	LEAD	PRLED	ENTER	FREQ	ADULT
TOTMHDM	.04	.12	.	.01	.16	-.04	.28*
TOTSTDM	-.01	.02	.	-.03	.18	-.09	.33*
TOTDAM	.02	.02	.	.02	.08	-.08	.34*
DAMAVOD	-.17	-.18	.	.30*	.47*	-.27*	.26*
DAMPROP1	.51*	.17	.	-.25*	-.19	.19	-.14
DAMPROP2	.50*	.32*	.	-.17	-.24*	.29*	-.05
DAMPROP3	.53*	.22*	.	-.09	-.05	.22*	-.16
DAMPROP4	.09	-.01	.	-.03	-.10	.09	-.09
MOVE	-.15	-.10	.	.29*	.42*	-.26*	.29*
DAMAVOD1	-.30*	-.23*	.	.24*	.39*	-.23*	-.08

Note :

For definitions of variables, see Table A4.14.

* Represents two-tailed significance at 95% level, but many are true at 99% level.

The variable LEAD is not applicable as no formal warning was given in case of major river flood.

'-' Those for which correlations are not logical.

Table A4.19: Correlations of selected key-variables

Flood type : Flash flood

Correlations:	VALGF	INVAL	INTER	AREAC	AREAG	COND
TOTMHDM	-.23*	-	-.02	-	-.12	-.24*
TOTSTDM	-.07	-	.11	-	-.01	-.07
TOTDAM	.24*	.59*	-	.20	.26*	-
DAMAVOD	-	.75*	-	.06	.51*	-
DAMPROP1	-.48*	-	-.34*	-	-.43*	-.44*
DAMPROP2	-	-.33*	-	-.05	-.36*	-
DAMPROP3	-	-.31*	-	-.11	-.32*	-
DAMPROP4	-	-	-	-	-	-
MOVE	-	.85*	-	.15	.56*	-
DAMAVOD1	-	.35*	-	-.06	.37*	-

Correlations:	DEPTH	DUR	LEAD	PRLED	ENTER	FREQ	ADULT
TOTMHDM	.30*	.30*	.05	.20	-.21	-.17	.16
TOTSTDM	.34*	.24*	.17	.18	-.21	-.14	.23*
TOTDAM	.04	-.06	.06	.30*	.08	.04	.31*
DAMAVOD	-.09	-.22*	.18	.34*	.13	-.04	-.12
DAMPROP1	.26*	.44*	-.00	.11	-.17	-.13	-.16
DAMPROP2	.32*	.36*	-.03	.07	-.13	-.10	-.18
DAMPROP3	.26*	.35*	.01	.15	-.12	-.15	-.11
DAMPROP4	.20	.26*	-.11	.05	-.07	.01	.28*
MOVE	-.10	-.25*	.20	.41*	.17	.01	.10
DAMAVOD1	-.21	-.23*	.12	.28*	.11	-.14	-.11

Note :

For definitions of variables, see Table A4.14.

* Represents two-tailed significance at 95% level, but many are true at 99% level.

'-' Those for which correlations are not logical.

Table A4.20: Correlations of selected key-variables
Flood type : Tidal flood

Correlations:	VALGF	INVAL	INTER	AREAC	AREAG	COND
TOTMHDM	.28*	-	.37*	-	.40*	.11
TOTSTDM	.39*	-	.51*	-	.58*	.17
TOTDAM	.39*	.85*	-	.43*	.44*	-
DAMAVOD	-	.91*	-	.41*	.45*	-
DAMPROP1	-.57*	-	-.44*	-	-.31*	-.31*
DAMPROP2	-	-.40*	-	-.24	-.28*	-
DAMPROP3	-	-.37*	-	-.23	-.27*	-
DAMPROP4	-	-	-	-	-	-
MOVE	-	.88*	-	.46*	.53*	-
DAMAVOD1	-	.36*	-	.07	.17	-

Correlations:	DEPTH	DUR	LEAD	PRLED	ENTER	FREQ	ADULT
TOTMHDM	.15	.19	.11	-.08	.13	.09	.02
TOTSTDM	.05	.12	.10	-.02	.07	.02	.23
TOTDAM	-.10	.04	.12	.11	.02	-.11	.73*
DAMAVOD	-.26*	-.19	.16	.41*	.01	-.19	.68*
DAMPROP1	.58*	.27*	-.08	.04	.09	.02	-.28*
DAMPROP2	.71*	.46*	-.03	-.26*	-.03	.22	-.23
DAMPROP3	.71*	.46*	-.03	-.20	-.03	.22	-.24
DAMPROP4	.26*	.13	-.17	.14	.25*	-.00	.02
MOVE	-.29*	-.22	.16	.46*	-.01	-.21	.62*
DAMAVOD1	-.38*	-.25*	.12	.53*	-.01	-.24	.04

Note :

For definitions of variables, see Table A4.14.

* Represents two-tailed significance at 95% level, but many are true at 99% level.

'-' Those for which correlations are not logical.

Table A4.21: Recovery and adjustment activities

	Flood type/Area		
	River flood	Flash flood	Tidal flood
% of structural damage recovered	59.8	43.5	83.2
Period to recover struct damage (days)*	219	27	42
% of struct. repairs undertaken by family members	15.3	41.9	11.6
% of struct. repairs undertaken by hired workers	84.7	58.1	88.4
% of clean-up works undertaken by family members	66.8	87.3	51.6
% of clean-up work undertaken by hired workers	33.2	12.7	48.4
Structural measures undertaken ** (% households)			
- Raising floor/ground level	31.3	6.6	20.0
- Constructed bund/dykes	21.5	0.8	13.3
- Plantation	1.4	-	-
- Constructed 'dua'	5.6	-	-
- Others	3.5	-	-
- No measures undertaken	36.7	92.6	66.7
Compensation measures undertaken***			
Loans from Inst. sources - % of HH	9.0	2.5	3.3
- % of supports	6.6	3.1	2.4
Loans from friends/relatives- % of HH	93.1	42.6	62.2
- % of supports	72.8	54.8	46.3
Government help - % of HH	5.5	18.0	22.2
- % of supports	2.7	21.5	10.6
Savings - % of HH	11.8	4.4	21.1
- % of supports	8.0	5.1	11.2
Sub-occupations - % of HH	8.3	3.3	4.4
- % of supports	4.8	3.4	2.1
Other supports (e.g. from employers) - % of HH	7.6	6.6	27.8
- % of supports	5.1	12.1	27.4

Note : * Refers to those who had some recovery;most people were unsure when to recover fully.
** Immediately before,during and after flood; *** During and after flood. The opportunity costs of repair works undertaken by family members were taken as 50%; most respondents took help from more than one source, so that percentages do not add to 100.

Table A4.22: Type of help received from and offered to respondents during flood

Help received/offered	Flood type/Area		
	Major river flood	Flash flood	Tidal flood
If helped anyone with evacuation or relief operations (% of households)	63.9	12.3	7.8
- Yes, helped relatives	37.9	93.3	100.0
- Yes, helped those working for me	5.4	-	46.7
- Yes, helped friends/neighbours	54.3	6.7	42.9
- Yes, helped unknown people	29.3	-	-
- No, I was busy with own affairs	31.9	85.2	90.0
- No, I was not fit	4.2	2.4	2.2
If received help in (% of households)	34.7	54.1	91.1
- Yes, in moving goods	44.0	34.8	12.2
- Yes, in treating sick	14.0	1.5	3.7
- Yes, in getting shelter	50.0	57.6	89.0
- Yes, in getting food	38.0	3.0	4.9
- Yes, in cleaning-up	-	6.1	-
- Yes, in financial aspects	20.0	47.0	8.5
- No, didn't receive any help	65.3	45.9	8.9
Community spirit * (% of households)			
- Heightened	50.0	24.6	18.9
- Lessened	29.9	68.9	73.3
- Same	20.1	6.6	7.8
If multi-storeyed residents came forward to help (% of households) **			
- Yes, all	10.4	-	1.1
- Yes, many	25.0	0.8	3.3
- Yes, some	33.3	4.1	5.6
- Very few	27.1	9.0	50.0
- None	1.4	33.6	38.9
- Not aware	2.8	52.5	1.1
Role of affluent section (% of households)			
- Did their best to help	16.7	14.8	1.1
- Offered limited help	45.8	53.3	8.9
- Rarely came forward	34.7	27.0	48.9
- Did not come forward at all	0.7	0.8	38.9
- Not sure	2.1	4.1	2.2

* Community refers to only local community, not any from outside.
** There are very few multi-storeyed building in case of flash flood area.

Table A4.23: Indirect impact on households: income, employment and health aspects

Damage components /House type	Flood type		
	River flood	Flash flood	Tidal flood
<u>Health aspects</u>			
Average members health affected			
- BB htype	2.4	2.3	2.4
- BC htype	2.0	-	2.4
- MC htype	1.7	1.9	2.3
- MT htype	2.0	1.5	2.0
- MM htype	-	1.3	-
- ALL	2.0	1.7	2.3
Additional medical expenses as % of monthly cost			
- BB htype	105.7	18.2	105.6
- BC htype	100.1	-	157.4
- MC htype	91.2	143.2	232.2
- MT htype	144.0	123.2	161.9
- MM htype	-	141.4	-
- ALL	106.8	51.4	152.6
<u>Income & employment</u>			
Per HH loss of person days			
- BB htype	49	14	17
- BC htype	33	-	20
- MC htype	42	18	48
- MT htype	52	22	16
- MM htype	-	25	-
- ALL	44	20	22
Income loss(92/93TK)			
- BB htype	9807	1766	2674
- BC htype	5410	-	2973
- MC htype	4447	1943	7032
- MT htype	3481	625	1249
- MM htype	-	1167	-
- ALL	5786	1367	2885
Income loss as % of monthly income			
- BB htype	102	41	48
- BC htype	182	-	55
- MC htype	83	62	157
- MT htype	113	78	41
- MM htype	-	71	-
- ALL	120	65	62

Note :

Distribution of sample in case of flash flood was skewed, and only 15 (out of 122) responded these questions.

Table A4.24: Indirect impacts : income and employment opportunities in three urban areas

	Urban area/flood type			
	River flood		Tidal flood	
	(1)	(2)	(1)	(2)
Employment opportunities				
- Remained same	30.6	0.0	27.8	0.0
- Declined	59.7	33.4	66.7	52.1
- Increased	5.6	17.1	4.4	36.3
Income opportunities				
- Remained same	22.9	0.0	22.2	0.0
- Declined	70.1	44.5	74.4	50.1
- Increased	2.1	28.3	3.3	56.7
Consumption of food items				
- Remained same	27.1	0.0	34.4	0.0
- Declined	71.5	15.4	61.1	22.1
- Increased	0.7	10.0	1.1	25.0
Consumption of industrial items				
- Remained same	18.1	0.0	11.1	0.0
- Declined	71.5	20.6	78.9	30.8
- Increased	-	-	-	-
Price of food items				
- Remained same	-	-	2.2	0.0
- Declined	9.7	24.4	1.1	15.0
- Increased	90.3	22.7	95.6	26.2
Price of industrial items				
- Remained same	34.0	0.0	3.3	0.0
- Declined	16.0	16.7	2.2	37.5
- Increased	39.6	17.2	92.2	34.7
Wage rate of agricult activities				
- Remained same	31.9	0.0	38.9	0.0
- Declined	31.3	17.3	14.4	31.9
- Increased	6.9	14.5	12.2	23.1
Wage rate of industrial activities				
- Remained same	30.6	0.0	42.2	0.0
- Declined	16.7	13.2	11.1	25.6
- Increased	-	-	-	-

Note: (1) represents % of households,and (2) represents % change suggested. Households in the case of flash flood did not respond; in other areas, not all households responded so that totals do not add to 100.

APPENDIX A5: APPENDIX TABLES AND FIGURES: COMMERCIAL SECTOR

Table A5.1: Basic characteristics of sample industrial enterprises : selected areas

(All values in 000 TK at 92/93 price)

Industry type /Characteristics	Area/Flood type		
	Tangail (Major river flood)	Bahubal (Flash flood)	Khatunganj (Tidal flood)
Food and agro-based			
: Fixed capital	2535	146	862
: Stock	267	24	676
: Output (monthly)	538	140	729
: Floor space (sq m)	117	138	355
: Sample size	11	7	9
Cotton and textiles			
: Fixed capital	106	102	185
: Stock	179	46	3019
: Output(monthly)	202	15	693
: Floor space(sq m)	296	36	456
: Sample size	11	1	4
Timber & furniture			
: Fixed capital	117	73	133
: Stock	70	81	124
: Output (monthly)	49	83	56
: Floor space (sq m)	38	26	107
: Sample size	5	6	3
Engineering & electrical			
: Fixed capital	86	42	111
: Stock	33	5	51
: Output (monthly)	35	12	30
: Floor space (sq m)	20	22	42
: Sample size	13	10	6
Miscellaneous & service			
: Fixed capital	154	97	855
: Stock	57	126	175
: Output (monthly)	64	402	141
: Floor space (sq m)	56	30	357
: Sample size	18	8	9
All industries			
: Fixed capital	759	86	771
: Stock	116	55	659
: Output (monthly)	172	151	353
: Floor space (sq m)	104	50	284
: Sample size	58	32	31

Note : All figures represent averages

Table A5.2: Basic characteristics of sample <u>business</u> enterprises : selected areas

(All values in 92/93 TK)

Industry type /Characteristics	Area/Flood type		
	Tangail (Major river flood)	Bahubal (Flash flood)	Khatunganj (Tidal flood)
Food and grocery			
: Fixed capital	57	82	168
: Stock	117	80	36
: Turnover (monthly)	170	123	800
: Floor space (sq m)	20	27	90
: sample size	10	12	15
Cloth & footwear			
: Fixed capital	89	34	93
: Stock	238	155	244
: Turnover (monthly)	93	60	401
: Floor space (sq m)	24	18	41
: sample size	6	4	3
Drugs & chemicals			
: Fixed capital	157	54	132
: Stock	788	95	558
: Turnover (monthly)	620	75	174
: Floor space (sq m)	42	24	55
: sample size	5	4	3
Electrical & electronics			
: Fixed capital	101	-	77
: Stock	290	-	84
: Turnover(monthly)	304	-	42
: Floor space(sq m)	17	-	42
: sample size	3	-	1
Motor/cycle parts			
: Fixed capital	106	29	82
: Stock	235	38	209
: Turnover (monthly)	354	30	52
: Floor space (sq m)	14	16	30
: sample size	5	2	1
Construction materials			
: Fixed capital	72	83	177
: Stock	411	127	307
: Turnover (monthly)	366	104	497
: Floor space (sq m)	30	35	47
: sample size	4	5	4
Miscellaneous			
: Fixed capital	61	27	68
: Stock	75	51	181
: Turnover (monthly)	51	30	47
: Floor space (sq m)	20	19	54
: sample size	9	4	3
All industries			
: Fixed capital	85	62	142
: Stock	260	93	329
: Turnover (monthly)	237	88	532
: Floor space (sq m)	23	25	69
: sample size	42	31	30

Note : All figures represent averages

Table A5.3: Damage variabilities in sample <u>industrial</u> enterprises : selected areas

(All values in 000 TK at 92/93 price)

Industry type/characteristics	Major river flood		Flash flood		Tidal flood	
	Standard deviation (000) [1]	Maximum as no of times of minimum	Standard deviation (000) [1]	Maximum as no of times of minimum	Standard deviation (000) [1]	Maximum as no of times of minimum
Food and agro-based						
: Total capital	7805	730	106	10	1249	37
: Annual output	9777	500	2015	50	12193	200
: Stock damage potential	88	1753	5	13300	726	441
: Floor space (sq m)	172	21	259	28	290	23
Cotton and textiles						
: Total capital	2724	751	-	-	6769	17
: Annual output	4034	267	-	-	11213	13
: Stock damage potential	80	364	-	-	2920	34
: Floor space (sq m)	829	398	-	-	629	19
Timber & furniture						
: Total capital	230	48	149	11	206	5
: Annual output	437	10	1587	35	507	3
: Stock damage potential	77	12	47	357	32	2
: Floor space (sq m)	24	8	7	2	126	16
Engineering & electrical						
: Total capital	109	79	26	4	171	52
: Annual output	420	167	105	10	444	25
: Stock damage potential	25	52696	1	3700	7	20
: Floor space (sq m)	15	14	6	2	27	4
Miscellaneous & service						
: Total capital	210	143	485	154	2002	102
: Annual output	1404	225	13081	775	3616	90
: Stock damage potential	14	140296	18	458	115	29
: Floor space (sq m)	96	49	19	4	651	56
All industries						
: Total capital	3614	6129	253	154	2857	1580
: Annual output	5034	3333	6580	1033	8384	750
: Stock damage potential	60	287435	23	125000	726	5852
: Floor space (sq m)	372	697	124	52	443	122

Note:[1] Standard deviation for capital, output and stock damage expressed in 000; T capital excludes value of land.
: - The case either not available or with only one observation

Table A5.4: Damage variabilities in sample business enterprises : selected areas

(All values in 92/93 TK)

Business type/characteristics	Major river flood		Flash flood		Tidal flood	
	Standard deviation (000) [1]	Maximum as no of times of minimum	Standard deviation (000) [1]	Maximum as no of times of minimum	Standard deviation (000) [1]	Maximum as no of times of minimum
Food and grocery						
: Total capital	156	41	106	7	321	8
: Annual turnover	2828	85	1931	75	11470	150
: Stock damage potential	45	130 Thou	16	7	153	75
: Floor space (sq m)	13	19	13	19	60	9
Cloth & footwear						
: Total capital	589	3	253	16	29	1
: Annual turnover	7518	6	196	2	6699	13
: Stock damage potential	30	5	12	8	38	3
: Floor space (sq m)	13	2	13	29	4	1
Timber & furniture						
: Total capital	137	7	42	2	393	4
: Annual turnover	2509	17	770	8	1578	6
: Stock damage potential	157	6	18	4	21	20
: Floor space (sq m)	2	3	7	2	30	4
Electrical & electronics						
: Total capital	219	2	-	-	-	-
: Annual turnover	5956	4	-	-	-	-
: Stock damage potential	32	3	-	-	-	-
: Floor space (sq m)	7	1	-	-	-	-
Motor/cycle parts						
: Total capital	485	8	6	1	-	-
: Annual turnover	5886	30	0	1	-	-
: Stock damage potential	9	2	3	2	-	-
: Floor space (sq m)	6	4	5	2	-	-
Construction materials						
: Total capital	106	11	156	6	235	3
: Annual turnover	605	27	1340	12	6528	24
: Stock damage potential	15	4	25	21	56	3
: Floor space (sq m)	9	2	19	3	22	3
Miscellaneous						
: Total capital	358	8	42	4	168	6
: Annual turnover	4305	23	177	3	63	1
: Stock damage potential	9	4	10	10	50	20
: Floor space (sq m)	12	5	4	2	20	2
All industries						
: Total capital	358	130	127	16	294	17
: Annual turnover	4305	222	1366	75	9196	150
: Stock damage potential	91	445 Thou	17	28	131	120
: Floor space (sq m)	12	28	13	63	49	12

Note:[1] Standard deviation for capital, output and stock damage expressed in 000; T capital excludes value of land.
: - The case either not available or with only one observation; Thou = Thousand

Table A5.5: Thresholds of depth and duration for different damage components in sample INDUSTRIES and BUSINESS units

Industries : Tangail

Type of industries /business	Thresholds for DEPTHS(cm)		Thresholds for DURATIONS (days)	
	Machinery /Equipment	Stock	Machinery /Equipment	Stock
Food & agro-based	19	7	4.7	1.6
St deviation	23	9	3.0	1.1
Cotton & textiles	9	8	3.4	1.5
St deviation	4	6	2.1	1.2
Timber & furniture	13	8	6.2	8.2
St deviation	11	5	3.1	3.9
Engineering	16	20	2.5	8.3
St deviation	20	37	2.1	16.4
Miscell & service	12	11	4.0	1.8
St deviation	13	22	3.0	1.7
ALL INDUSTRIES	14	11	3.9	3.7
St deviation	16	21	2.8	8.1

Business : Tangail

Food & grocery	22	5	5.2	1.2
St deviation	39	3	3.4	0.4
Cloth & footwear	5	3	3.0	1.2
St deviation	0	-	-	0.4
Drugs & chemicals	-	-	-	1.0
St deviation	-	-	-	0.0
Electrical	3	1	1.0	1.0
St deviation	-	-	-	0.0
Motor/cycle parts	11	3	2.5	1.4
St deviation	2	7	0.7	0.9
Construction	8	7	7.0	2.0
St deviation	-	-	-	1.2
Miscellaneous	17	2	2.0	1.2
St deviation	3	2	2.0	0.4
ALL BUSINESS	15	4	3.6	1.3
St deviation	23	3	2.8	0.6

Note : All figures represent averages; - Not available;
: Machinery/equipemnt for business includes furniture and other equipment, if any.

Table A5.6: Results of flood loss models (linear): industrial units: Tangail

A:STRUCTURE

Damage component	Model form	Industry group	Coefficient of main variables		
			Intercept	Depth	Duration
STRUCTURE -Absolute damage, assumed no damage-reducing activity	Linear	ALL INDUSTRIES	-4968	9683	-3002
		Food & agro based	-19504	29337	-2372
		Cotton & other textile	-3435	7074	-2461
		Timber & furniture	-4884	4886	-1379
		Engineering	-873	3637	-616
		Miscellaneous service	-3376	4587	-888

Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
	I1	I2	I3	I4		
35.53	23730	-2994	1961	68	.43	p<.00
215	-	-	-	-	.63	p<.00
27	-	-	-	-	.96	p<.00
176	-	-	-	-	.40	p<.01
34	-	-	-	-	.04	p<.17
71	-	-	-	-	.66	p<.00

B: MACHINERY

Damage component	Model form	Industry group	Coefficient of main variables		
			Intercept	Depth	Duration
MACHINER/ EQUIPT -Absolute damage, adjusted for damage-reducing activity	Linear	ALL INDUSTRIES	-19506	37741	-8987
		Food & agro based	-19028	152065	6329
		Cotton & other textile	-75	25673	-2847
		Timber & furniture	-11421	12616	-3097
		Engineering	-10646	11663	-1575
		Miscellaneous service	2513	14006	-4182

Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
	I1	I2	I3	I4		
68	73681	-3074	3616	2729	.13	p<.00
1176	-	-	-	-	.83	p<.00
22	-	-	-	-	.11	p<.06
452	-	-	-	-	.14	p<.15
423	-	-	-	-	.39	p<.00
3	-	-	-	-	.02	p<.22

Table A5.6 (contd)

C: STOCK

Damage component	Model form	Industry group	Coefficient of main variables		
			Inter cept	Depth	Duration
STOCK -Absolute damage, adjusted for damage-reducing activity	Linear	ALL INDUSTRIES	-9673	51556	-14734
		Food & agro based	-483	86131	-23069
		Cotton & other textile	-11382	57596	-18250
		Timber & furniture	-18578	27023	-6236
		Engineering	-28524	21477	-2224
		Miscellaneous service	-16800	28012	1545

Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
	I1	I2	I3	I4		
91.9	58506	-3170	2009	-13100	.38	p<.00
280.2	-	-	-	-	.24	p<.00
75.6	-	-	-	-	.53	p<.00
889.4	-	-	-	-	.20	p<.13
1399.5	-	-	-	-	.41	p<.00
1544.7	-	-	-	-	.74	p<.00

D: VALUE ADDED

Damage component	Model form	Industry group	Coefficient of main variables		
			Inter cept	Depth	Duration
VALUE ADDED LOSS -Absolute damage, adjusted for recovery	Linear	ALL INDUSTRIES	-53014	113336	-49683
		Food & agro based	-344442	342003	-36513
		Cotton & other textile	-32134	173259	-68125
		Timber & furniture	-28202	38985	-13268
		Engineering	7636	25877	-10679
		Miscellaneous service	-3985	25808	-13292

Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
	I1	I2	I3	I4		
289.8	204133	30568	1251	14950	.26	p<.00
2791.1	-	-	-	-	.79	p<.00
178.7	-	-	-	-	.43	p<.00
885.7	-	-	-	-	.57	p<.00
804.3	-	-	-	-	.09	p<.06
486.3	-	-	-	-	.70	p<.00

Table A5.7: Results of flood loss models (Log-log) : industrial units

A:STRUCTURE

Damage component	Model form	Industry group	Coefficient of main variables			Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
			Inter cept	Depth	Duration		I1	I2	I3	I4		
STRUCTURE -Absolute damage, assumed no damage-reducing activity	Log-log	ALL INDUSTRIES	4.8104	.6280	-.1308	.8238	.9051	.2523	.5538	.2486	.55	$p<.00$
		Food & agro based	3.5912	.5046	-.1470	1.3130	-	-	-	-	.34	$p<.00$
		Cotton & other textile	5.3700	.5654	-.1688	.7412	-	-	-	-	.93	$p<.00$
		Timber & furniture	3.8209	.3244	-.0225	1.2466	-	-	-	-	.55	$p<.00$
		Engineering	5.2518	.8764	-.1650	.7797	-	-	-	-	.25	$p<.00$
		Miscellaneous service	5.1901	.8426	-.0546	.7109	-	-	-	-	.35	$p<.00$

B: MACHINERY

Damage component	Model form	Industry group	Coefficient of main variables			Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
			Inter cept	Depth	Duration		I1	I2	I3	I4		
MACHINERE QUIP -Absolute damage, adjusted for damage-reducing activity	Log-log	ALL INDUSTRIES	5.3436	.4757	-.3144	1.0293	.2705	-.4664	-.4703	.8017	.40	$p<.00$
		Food & agro based	1.5990	.5301	-.1802	1.9303	-	-	-	-	.77	$p<.00$
		Cotton & other textile	5.1268	.5758	-.4912	.9903	-	-	-	-	.47	$p<.00$
		Timber & furniture	3.4292	-.0375	-.4146	1.4359	-	-	-	-	.10	$p<.21$
		Engineering	5.8366	.7148	-.1372	1.1359	-	-	-	-	.47	$p<.00$
		Miscellaneous service	7.2017	.6846	-.3306	.4855	-	-	-	-	.06	$p<.10$

Table A5.7 (contd):

C:STOCK

Damage component	Model form	Industry group	Coefficient of main variables		
			Inter cept	Depth	Duration
STOCK -Absolute damage, adjusted for damage-reducing activity	Log-log	ALL INDUSTRIES	5.9509	.6324	-.2825
		Food & agro based	3.4992	.8044	-.3550
		Cotton & other textile	6.6473	.5439	-.1084
		Timber & furniture	7.5666	.2674	-.1875
		Engineering	6.9804	.8750	-.0926
		Miscellaneous service	5.6680	.6363	-.2789

Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
	I1	I2	I3	I4		
1.0109	.3821	.1421	.8857	.2543	.50	p<.00
1.6846	-	-	-	-	.44	p<.00
.8426	-	-	-	-	.72	p<.00
.7495	-	-	-	-	.20	p<.13
.7258	-	-	-	-	.08	p<.16
1.0968	-	-	-	-	.42	p<.00

D: VALUE ADDED

Damage component	Model form	Industry group	Coefficient of main variables		
			Inter cept	Depth	Duration
VALUE ADDED LOSS -Absolute loss, adjusted for recovery	Log-log	ALL INDUSTRIES	6.8974	.5346	-.3461
		Food & agro based	2.9371	.6891	-.2601
		Cotton & other textile	8.1600	.6376	-.3774
		Timber & furniture	7.2157	.7061	-.4013
		Engineering	7.1600	.3819	-.3022
		Miscellaneous service	7.4084	.5535	-.2904

Area	Coefficient of dummy variables for IGROUP				Adj R^2	F
	I1	I2	I3	I4		
.9248	.3534	.6223	.2677	.7614	.45	p<.00
.6891	-	-	-	-	.58	p<.00
.7603	-	-	-	-	.64	p<.00
.9287	-	-	-	-	.72	p<.00
1.0884	-	-	-	-	.22	p<.00
.7639	-	-	-	-	.29	p<.00

Table A5.8: Results of flood loss models (Linear) : <u>business</u> enterprises : Tangail

A : STRUCTURE

Damage component	Model form	Business group	Coefficient of main variables		
			Inter cept	Depth	Dura tion
STRUCTURE -Absolute damage, assumed no damage-reducing activity	Linear	ALL GROUPS	-346	2107	-389
		Food & grocery	-3286	1464	-155
		Cloth & footwear	23793	4147	-855
		Drugs & chemicals	-9769	4810	-936
		Electrical & electronics	-21928	2456	-262
		Motor/cycle parts	4225	522	-167
		Construction materials	1892	1001	-352
		Miscellaneous	707	1756	-246

Area	Coefficient of dummy variables for BGROUP						Adj R^2	F
	B1	B2	B3	B4	B5	B6		
177	-811	1767	-620	2653	-91	-4384	.15	p<.00
299	-	-	-	-	-	-	.15	p<.04
-814	-	-	-	-	-	-	.40	p<.00
336	-	-	-	-	-	-	.66	p<.00
1553	-	-	-	-	-	-	-.01	P<.46
-69	-	-	-	-	-	-	-.14	P<.90
-14	-	-	-	-	-	-	.06	P<.31
135	-	-	-	-	-	-	.15	p<.04

Table A5.8 (contd)

B : STOCK

Damage component	Model form	Business group	Coefficient of main variables		
			Inter cept	Depth	Dura tion
STOCK -Absolute damage, adjusted for damage-reducing activity	Linear	ALL GROUPS	-137816	77064	2682
		Food & grocery	-51728	63053	-606
		Cloth & footwear	-10911	53810	-7164
		Drugs & chemicals	-443366	306641	7301
		Electrical & electronics	-248110	82554	-6480
		Motor/cycle parts	5694	32858	-6696
		Construction materials	31640	28691	-8595
		Miscellaneous	-9197	16164	-833

Area	Coefficient of dummy variables for BGROUP						Adj R^2	F
	B1	B2	B3	B4	B5	B6		
4474	48705	20651	247019	80109	60030	-37307	.66	p<.00
3323	-	-	-	-	-	-	.45	p<.00
1043	-	-	-	-	-	-	.08	p<.21
12800	-	-	-	-	-	-	.53	p<.00
15348	-	-	-	-	-	-	.38	P<.08
1193	-	-	-	-	-	-	.53	P<.00
-919	-	-	-	-	-	-	.10	P<.25
664	-	-	-	-	-	-	.29	p<.00

Table A5.8 (contd) :

C : TURNOVER

Damage component	Model form	Business group	Coefficient of main variables		
			Inter cept	Depth	Dura tion
PRIMARY INDIRECT DAMAGE-GROSS MARGIN-absolute damage, adjusted for recovery	Linear	ALL GROUPS	-194822	90290	-32083
		Food & grocery	20846	37453	-13320
		Cloth & footwear	53389	13916	-8296
		Drugs & chemicals	-1352428	570477	-219016
		Electrical&electronic	-285523	79466	-30910
		Motor/cycle parts	5635	18059	-5174
		Construction materials	-488906	52636	-27258
		Miscellaneous	-28463	29648	-4904

Area	Coefficient of dummy variables for BGROUP						Adj R^2	F
	B1	B2	B3	B4	B5	B6		
8804	-3264	-52174	466934	82547	42834	-47085	.52	$p<.00$
-544	-	-	-	-	-	-	.04	$p<.21$
-1450	-	-	-	-	-	-	.11	$p<.15$
39543	-	-	-	-	-	-	.58	$p<.00$
19319	-	-	-	-	-	-	-.07	$P<.15$
970	-	-	-	-	-	-	.09	$P<.22$
18018	-	-	-	-	-	-	.71	$P<.00$
2229	-	-	-	-	-	-	.09	$p<.11$

Table A5.9: Results of flood loss models (log-log) : <u>business</u> enterprises :TANGAIL

A : STRUCTURE

Damage component	Model form	Business group	Coefficient of main variables			Area	Coefficient of dummy variables for BGROUP						Adj R^2	F
			Inter cept	Depth	Dura tion		B1	B2	B3	B4	B5	B6		
STRUCTURE -Absolute damage, assumed no damage-reducing activity	Log-log	ALL GROUPS	7.1593	.2802	-.0917	.4417	-.9337	-.0311	.0030	.2714	-.1916	-.9317	.27	p<.00
		Food & grocery	5.8858	.3859	-.0870	.5664	-	-	-	-	-	-	.11	p<.08
		Cloth & footwear	19.9493	.3774	-.1238	-3.61	-	-	-	-	-	-	.62	p<.00
		Drugs & chemicals	.5555	.3635	-.1604	2.95	-	-	-	-	-	-	.88	p<.00
		Electrical & electronics	-1.3547	.3293	-.0360	3.52	-	-	-	-	-	-	.01	P<.42
		Motor/cycle parts	8.8783	.1198	-.0781	-.342	-	-	-	-	-	-	-.1	P<.73
		Construction materials	8.5459	.5247	-.2062	-.208	-	-	-	-	-	-	.15	P<.18
		Miscellaneous	6.9399	.2530	-.0480	.5095	-	-	-	-	-	-	.19	p<.00

Table A5.9 (contd):

B : STOCK

Damage component	Model form	Business group	Coefficient of main variables		
			Inter cept	Depth	Dura tion
STOCK -Absolute damage, adjusted for damage-reducing activity	Log-log	ALL GROUPS	7.2079	.6984	-.1278
		Food & grocery	8.3913	.6547	.0200
		Cloth & footwear	9.7675	.7579	-.1676
		Drugs & chemicals	7.1829	.5869	.0688
		Electrical & electronics	2.5146	.6906	-.0044
		Motor/cycle parts	10.0557	.4521	-.1744
		Construction materials	11.8858	.9779	-.4956
		Miscellaneous	7.4103	.8665	-.1615

Area	Coefficient of dummy variables for BGROUP						Adj R^2	F
	B1	B2	B3	B4	B5	B6		
.8306	1.4756	1.1110	2.5123	1.8758	1.6688	-.0172	.74	$p<.00$
.9164	-	-	-	-	-	-	.75	$p<.00$
.3803	-	-	-	-	-	-	.17	$p<.08$
1.497	-	-	-	-	-	-	.66	$p<.00$
3.122	-	-	-	-	-	-	.55	$P<.02$
.3282	-	-	-	-	-	-	.37	$P<.02$
-.488	-	-	-	-	-	-	.05	$P<.33$
.7755	-	-	-	-	-	-	.19	$p<.02$

Table A5.9 (contd) :

C: TURNOVER

Damage component	Model form	Business group	Coefficient of main variables				Coefficient of dummy variables for B GROUP						Adj R^2	F
			Inter cept	Depth	Dura tion	Area	B1	B2	B3	B4	B5	B6		
PRIMARY INDIRECT DAMAGE: GROSS MARGIN -Absolute damage, adjusted for recovery	Log-log	ALL GROUPS	8.3725	.5069	-.2824	.6445	.0609	-.2136	2.4538	1.2044	.4147	.1075	.54	p<.00
		Food & grocery	8.6888	.6283	-.3307	.5697	-	-	-	-	-	-	.23	p<.01
		Cloth & footwear	13.6908	.6184	-.3301	-1.091	-	-	-	-	-	-	.25	p<.03
		Drugs & chemicals	3.0705	.4772	-.3583	-2.753	-	-	-	-	-	-	.73	p<.00
		Electrical & electronics	6.1822	.6260	-.3465	1.8549	-	-	-	-	-	-	-.20	p<.72
		Motor/cycle parts	7.9431	.4111	-.2277	.9626	-	-	-	-	-	-	.30	p<.01
		Construction materials	-17.52	.6647	-.4224	8.3566	-	-	-	-	-	-	.92	p<.00
		Miscellaneous	10.2351	.5051	-.1609	-.0341	-	-	-	-	-	-	-.0	p<.63

Table A5.10: Results of Cobb-Douglas production model ($A K^{\alpha} L^{\beta}$) : Industrial units

A : Main case study area

Industry group	Intercept	Capital coefficient	Labour coefficient	$\alpha + \beta$	Adj R^2	F
ALL INDUSTRIES	.8038	.5957	.5664	1.16	.77	100.3 ($p < .00$)
Food & agro-base	-1.2026	.5864	.9748	1.56	.70	12.9 ($p < .00$)
Cotton & textiles	2.1264	.6280	.2703	.90	.85	28.9 ($p < .00$)
Furniture & fixture	7.8657	-.3543	1.3369	.92	.90	54.9 ($p < .00$)
Engineering	-.6761	.9847	-.0906	.89	.77	21.1 ($p < .00$)
Miscelleneous	1.4345	.4299	.7845	1.21	.85	50.0 ($p < .00$)

B : All areas combined

ALL INDUSTRIES	.7388	.6601	.4288	1.09	.76	193.7 ($p < .00$)
Food & agro-base	.9124	.6707	.4420	1.11	.61	21.0 ($p < .00$)
Cotton & textiles	2.3724	.5442	.4072	.95	.87	53.1 ($p < .00$)
Furniture & fixture	3.6074	.3584	.6009	.96	.52	7.9 ($p < .00$)
Engineering	-.1648	.8557	.0860	.94	.73	38.7 ($p < .00$)
Miscelleneous	1.5772	.5121	.5604	1.07	.76	53.1 ($p < .00$)

Table A5.11: Results of Cobb-Douglas production model ($A K^{\alpha} L^{\beta}$) : <u>business units</u>

A : Main case study area

Business group	Intercept	Capital coefficient	Labour coefficient	$\alpha + \beta$	Adj R^2	F
ALL BUSINESS	.2014	.6739	.7628	1.44	.51	($p < .00$)
Food grocery & stationary	9.1366	.4046	-.5728	-.17	-.04	($p < .48$)
Cloth & footwear	-8.4957	1.2884	.8397	2.13	.13	($p < .38$)
Drugs & chemicals	-3.9571	.5801	1.9036	2.48	.78	($p < .11$)
Electrical & electronics	-	-	-	-	-	n is small
Motro/cycle parts	-1.5899	.8602	.7375	1.60	.75	($p < .12$)
Construction materials	-7.9347	1.3246	.8462	2.17	.92	($p < .04$)
Miscelleneous	-2.6159	1.2359	-.3572	.88	.29	($p < .15$)

B : Three areas concerned

Business group	Intercept	Capital coefficient	Labour coefficient	$\alpha + \beta$	Adj R^2	F
ALL BUSINESS	1.4214	.5044	.9404	1.44	.54	($p < .00$)
Food grocery & stationary	2.2859	.2922	1.3536	1.65	.50	($p < .00$)
Cloth & footwear	9.1448	-.2519	1.3176	1.07	.40	($p < .03$)
Drugs & chemicals	.7473	.6096	.7569	1.37	.68	($p < .00$)
Electrical & electronics	-14.9058	2.1579	-.0828	2.08	.90	($p < .08$)
Motro/cycle parts	-4.2740	1.3485	-.1669	1.18	.66	($p < .03$)
Construction materials	-4.2239	1.0573	.6784	1.74	.75	($p < .00$)
Miscelleneous	4.1424	.4715	.2097	.68	.15	($p < .14$)

Table A5.12: Results of flood loss models : Reduction Factors to total capital - industrial units

Damage component	Model form	Industries group /Area	Coefficient ofmain variables			Area	Coefficient of dummy variables for BGROUP				Adj R^2	F
			Intercept	Depth	Duration		I1	I2	I3	I4		
REDUCTION IN CAPITAL -adjusted for damage-reducing activity	Linear	All industries /Main study area	.2429	.0246	.0052	-7.5E-05	.0487	.0038	.1197	.0590	.00	p<.39
	Linear	All industries /All areas combined	.2454	.0374	-.1095	-7.2E-05	.0195	.0118	.0233	.0123	.08	p<.00
	Log-log	All industris /Main study area	-1.6300	-.0253	.1611	-.0386	.3116	-.1170	.5392	.0188	.04	p<.07
	Log-log	All industries /All areas combined	-1.3249	-.0238	-.4214	-.1087	.2250	.0286	-.2299	-.2568	.08	p<.00

Table A5.13: Results of flood loss models : Reduction Factors to total capital - business units

Damage component	Model form	Business group /Area	Coefficient ofmain variables				Coefficient of dummy variables for BGROUP						Adj R^2	F
			Intercept	Depth	Duration	Area	B1	B2	B3	B4	B5	B6		
REDUCTION IN CAPITAL -adjusted for damage-reducing activity	Linear	All business /Main study area	.0636	.2160	.0190	-.0032	.2532	.0447	.3217	.0487	.0539	.0166	.47	p<.00
	Linear	All business /All areas combined	.1259	.1464	-.0844	-.0014	.1625	.0192	.1885	.0255	.0668	.0087	.31	p<.00
	Log-log	All business /Main study area	-1.1463	.1812	.0594	-.2291	.8997	.2377	1.1203	.3770	.1407	-.7404	.44	p<.00
	Log-log	All business /All areas combined	-1.0069	.1231	-.4652	-.2284	.7484	.0651	.9155	.4021	.3557	-.2825	.30	p<.00

Table A5.14: Results of flood loss models : Evaluation of indirect (VALUE ADDED) loss - <u>industrial</u> units (<u>main study area</u>)

A : LINEAR

Damage component	Model form	Industry group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT DAMAGE -VALUE ADDED LOSS adjusted for recovery activity	Linear	ALL INDUSTRIES	-28954	1.5029
		Food & agro based	-68108	1.6077
		Cotton & other textile	8987	1.3927
		Timber & furniture	14044	.3883
		Engineering	37119	.1367
		Miscellaneous service	2240	.8163

Coefficient of dummy variables for IGROUP				Adj R^2	F
I1	I2	I3	I4		
-17828	27836	-11245	32598	.93	p<.00
-	-	-	-	.96	p<.00
-	-	-	-	.93	p<.00
-	-	-	-	.65	p<.00
-	-	-	-	-.01	p<.41
-	-	-	-	.85	p<.00

B : LOG-LOG

Damage component	Model form	Industry group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT DAMAGE -VALUE ADDED loss adjusted for recovery activity	Log-log	ALL INDUSTRIES	1.0343	.8928
		Food & agro based	-1.6512	1.1202
		Cotton & other textile	1.2405	.9280
		Timber & furniture	4.7775	.5164
		Engineering	1.3888	.9030
		Miscellaneous service	2.0058	.7927

Coefficient of dummy variables for IGROUP				Adj R^2	F
I1	I2	I3	I4		
-.1299	.5616	-.0775	.4503	.71	p<.00
-	-	-	-	.71	p<.00
-	-	-	-	.88	p<.00
-	-	-	-	.40	p<.00
-	-	-	-	.45	p<.00
-	-	-	-	.79	p<.00

Table A5.15: Results of flood loss models : Evaluation of indirect (VALUE ADDED) loss - industrial units (all areas combined)

A : LINEAR

Damage component	Model form	Industry group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT DAMAGE -VALUE ADDED loss adjusted for recovery activity	Linear	ALL INDUSTRIES	80217	.5184
		Food & agro based	-8758	1.4203
		Cotton & other textile	98937	.1888
		Timber & furniture	17001	.3316
		Engineering	15939	.3087
		Miscellaneous service	-21993	2.5579

Coefficient of dummy variables for IGROUP				Adj R^2	F
I1	I2	I3	I4		
50296	-55340	-68512	-67297	.22	p<.00
-	-	-	-	.52	p<.00
-	-	-	-	.34	p<.00
-	-	-	-	.28	p<.00
-	-	-	-	.07	p<.00
-	-	-	-	.29	p<.00

B : LOG-LOG

Damage component	Model form	Industry group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT DAMAGE -VALUE ADDED loss adjusted for recovery activity	Log-log	ALL INDUSTRIES	1.6374	.8331
		Food & agro based	.7505	.9106
		Cotton & other textile	1.4241	.8699
		Timber & furniture	8.0977	.1684
		Engineering	.9126	.8984
		Miscellaneous service	.1706	.9832

Coefficient of dummy variables for IGROUP				Adj R^2	F
I1	I2	I3	I4		
-.0424	.1762	.1609	-.1456	.58	p<.00
-	-	-	-	.50	p<.00
-	-	-	-	.81	p<.00
-	-	-	-	.03	p<.12
-	-	-	-	.33	p<.00
-	-	-	-	.77	p<.00

Table A5.16: Results of flood loss models: Evaluation of indirect(GROSS MARGIN) loss - business enterprises (main study area)

A : LINEAR

Damage component	Model form	Business group	Coefficient of main variables		Coefficient of dummy variables for BGROUP						Adj R^2	F
			Inter cept	Direct damage	B1	B2	B3	B4	B5	B6		
INDIRECT LOSS -GROSS MARGIN (on TURNOVER) loss, adjusted for recovery activity	Linear	All	44325	.2365	-17176	-27775	-45720	75642	-14348	54585	.20	p<.00
		Food & grocery	41416	.0362	-	-	-	-	-	-	-.02	p<.77
		Cloth & footwear	2877	.4432	-	-	-	-	-	-	.64	p<.00
		Drugs & chemicals	14478	.1942	-	-	-	-	-	-	.33	p<.00
		Electrical & electronics	-62231	2.2196	-	-	-	-	-	-	.85	P<.00
		Motor/cycle parts	31025	.2150	-	-	-	-	-	-	-.03	P<.51
		Construction materials	96691	.3212	-	-	-	-	-	-	-.07	P<.86
		Miscellaneous	-13544	2.9585	-	-	-	-	-	-	.38	p<.00

Table A5.16 (contd) :

B : LOG-LOG

Damage component	Model form	Business group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT LOSS -GROSS MARGIN (on TURNOVER) loss, adjusted for recovery activity	Log-log	ALL GROUPS	4.1047	.6326
		Food & grocery	3.4245	.6238
		Cloth & footwear	.0844	.9228
		Drugs & chemicals	-2.7934	1.0820
		Electrical & electronics	-4.6008	1.4247
		Motor/cycle parts	5.9686	.4121
		Construction materials	14.2411	-.3624
		Miscellaneous	4.2840	.6140

Coefficient of dummy variables for BGROUP						Adj R^2	F
B1	B2	B3	B4	B5	B6		
-.7757	-.8648	-1.2341	.2328	-.5008	.2814	.28	p<.00
-	-	-	-	-	-	.25	p<.00
-	-	-	-	-	-	.73	p<.00
-	-	-	-	-	-	.43	p<.00
-	-	-	-	-	-	.70	P<.00
-	--	-	-	-	-	-.01	P<.41
-	-	-	-	-	-	-.04	P<.50
-	-	-	-	-	-	.27	p<.00

Table A5.17: Results of flood loss models: Evaluation of indirect (GROSS MARGIN) loss - business enterprises (all areas combined)

A : LINEAR

Damage component	Model form	Business group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT LOSS - GROSS MARGIN loss, adjusted for recovery activity	Linear	All	19857	.3426
		Food & grocery	14654	.9918
		Cloth & footwear	27769	.1474
		Drugs & chemicals	13812	.1769
		Electrical & electronics	-31543	1.6167
		Motor/cycle parts	5152	.6111
		Construction materials	49341	-.0851
		Miscellaneous	-3283	1.7624

Coefficient of dummy variables for BGROUP						Adj R^2	F
B1	B2	B3	B4	B5	B6		
39866	-125	-42254	45686	-4167	15687	.10	p<.00
-	-	-	-	-	-	.15	p<.00
-	-	-	-	-	-	.00	p<.43
-	-	-	-	-	-	.45	p<.00
-	-	-	-	-	-	.86	P<.00
-	-	-	-	-	-	.24	P<.00
-	-	-	-	-	-	-.02	P<.73
-	-	-	-	-	-	.38	p<.00

Table A5.17 (contd) :

B : LOG-LOG

Damage component	Model form	Business group	Coefficient of main variables	
			Inter cept	Direct damage
INDIRECT LOSS - GROSS MARGIN loss, adjusted for recovery activity	Log-log	ALL GROUPS	2.2589	.7679
		Food & grocery	-.0193	.9381
		Cloth & footwear	6.5151	.3225
		Drugs & chemicals	-.2365	.8823
		Electrical & electronics	-2.7736	1.2445
		Motor/cycle parts	-5.5639	1.4634
		Construction materials	7.6253	.1898
		Miscellaneous	1.8235	.8148

Coefficient of dummy variables for BGROUP						Adj R^2	F
B1	B2	B3	B4	B5	B6		
-.4782	-.2346	-1.1866	.1731	-.6372	-.2804	.32	$p<.00$
-	-	-	-	-	-	.35	$p<.00$
-	-	-	-	-	-	.09	$p<.02$
-	-	-	-	-	-	.60	$p<.00$
-	-	-	-	-	-	.85	$P<.00$
-	--	-	-	-	-	.64	$P<.00$
-	-	-	-	-	-	.00	$P<.40$
-	-	-	-	-	-	.44	$p<.00$

DEPTH-DAMAGE CURVES : INDUSTRIES & BUSINESS

FIG A5.1: DEPTH DAMAGE CURVE
STOCK DAMAGE TO INDUSTRIES : TANGAIL

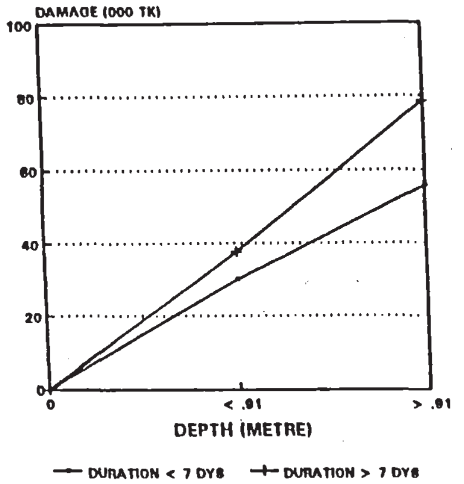


FIG A5.2: DEPTH DAMAGE CURVE
STOCK DAMAGE TO BUSINESS : TANGAIL

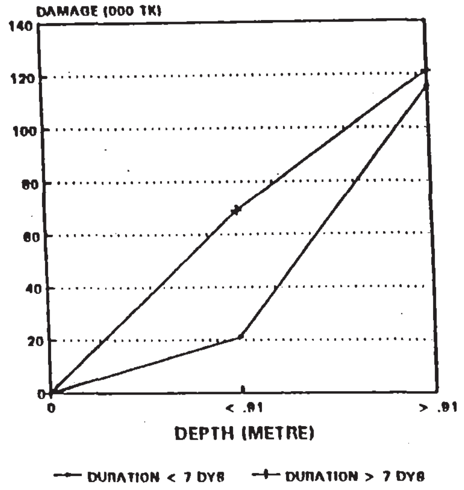
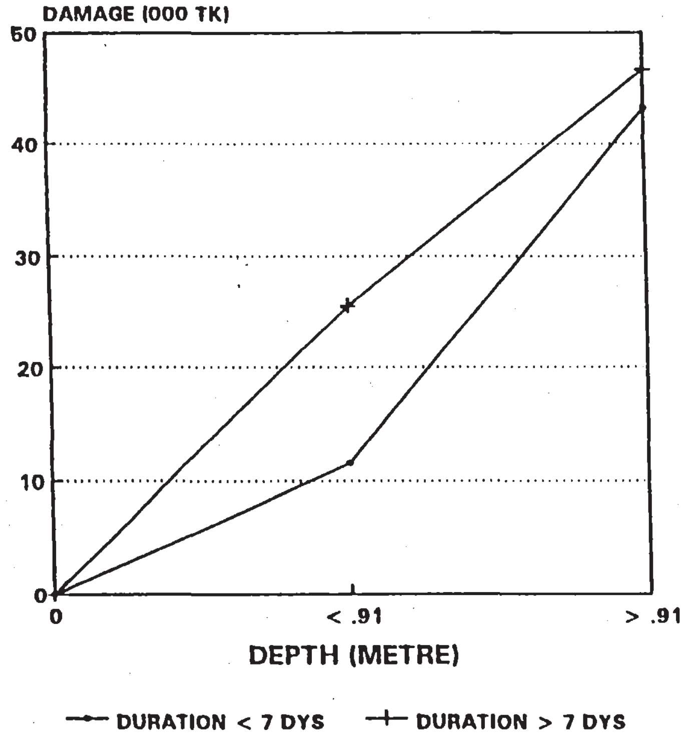


FIG A5.3: DEPTH DAMAGE CURVE
MACHINERY DAMAGE TO INDUSTRIES : TANGAIL



DEPTH-DAMAGE CURVES : SECTORS

FIG A5.4: DEPTH DAMAGE CURVE
SECTOR DAMAGE (INDUSTRY) : TANGAIL
(STRUCTURE + MACHINERY + STOCK)

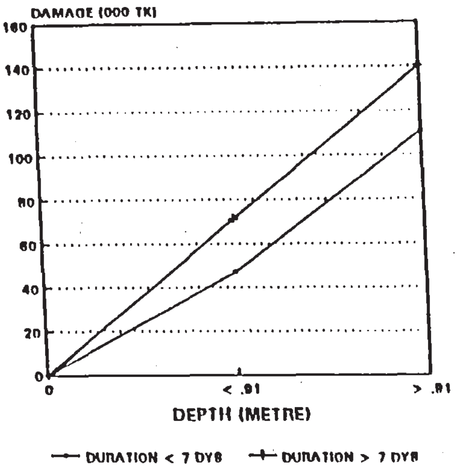


FIG A5.5: DEPTH DAMAGE CURVE
SECTOR DAMAGE (BUSINESS) : TANGAIL
(STRUCTURE + STOCK)

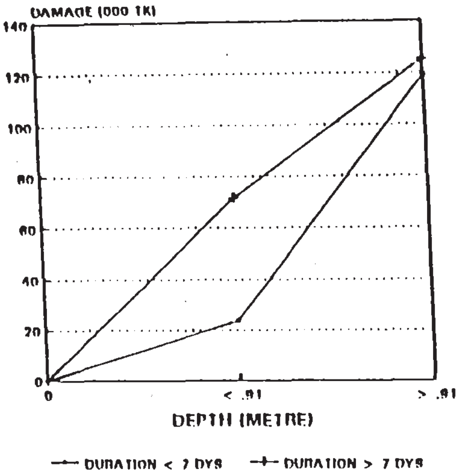


FIG A5.6: DEPTH DAMAGE CURVE
SECTOR DAMAGE (RESIDENTIAL) : TANGAIL
(STRUCTURAL + INVENTORY)

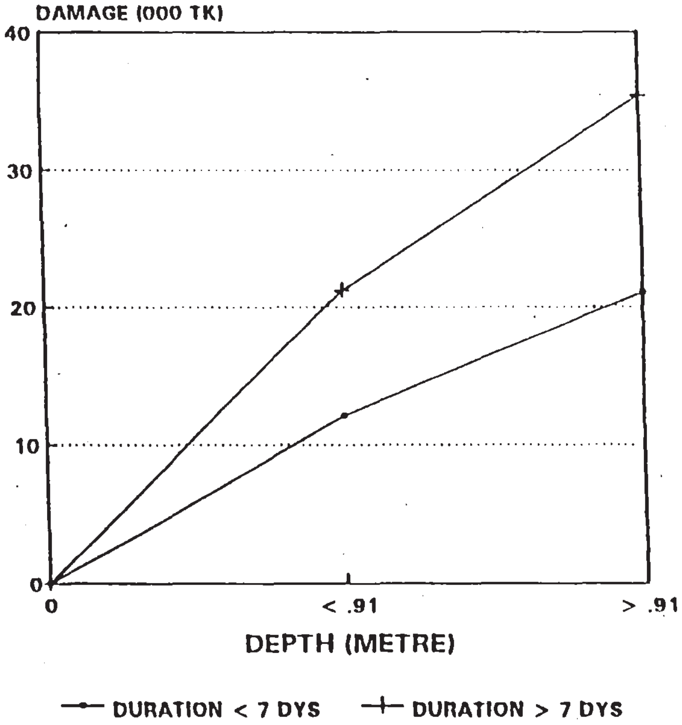


Table A5.18: Sector list with corresponding industries

Sector	Original sector code	New sector code	Industry code & industries
Rice	1	1	3119 :Rice milling :Rice production
Wheat	2	1	:Wheat production :Wheat processing
Coarse grains	3	6	3118 :Coarse grain milling :Coarse grain production
Jute	4	7	3253 :Jute processing :Jute production
Sugarcane	5	8	:Sugarcane production
Cotton	6	9	:Cotton production, ginning
Tobacco	7	10	3144 :Tobacco steam & redrying :Tobacco production
Potato	8	11	:Potato production
Other vaegitables	9	12	:Vegetables production
Pulses	10	13	:Pulses production
Oilseeds	11	14	:Oilseeds production
Fruits	12	15	3113 :Fruits & Vegetables :Fruits production
Tea	13	16	3126:Tea & coffee Processng 3127 :Tea & coffee blending :Tea production
Other crops	14	17	:Other crops production
Livestock	15	1	:Beef & sheep meat :Poultry meat & egg 3112 :Dairy production :Hides & skin
Fish	16	18	3114 :Fish&sea fish processing :Fish rearing & catching
Forestry	17	19	3311:Sawing
Other food	18	1	3121:Grain mill products 3122:Bakery products 3125:Confectionnaries 3131:Distilled & rect sprit 3134:Soft drink
Edible oil	19	1	3115:Hydro. vegetable oil 3116:Edible oil 3117:Vegetable & animal oil
Sugar & gur	20	20	3123 :Sugar mill & refinary :Gur making
Salt	21	21	Salt production & crushing
Yarn	22	2	Production of yarn
Cloth:mill	23	2	3201: Cotton textles 3207:Dying bleaching etc 3205:Narrow fabrics 3213:Knitting & hosiery 3216:Spooling & thread ball 3219:Other textiles
Cloth:handloom	24	2	3206:Handloom textiles
Readymade garments	25	2	3221:Ready made garments
Jute textiles	26	2	3203:Jute textiles

Table A5.18 (contd) :

Paper	27	22	3411:Pulp & paper
			3412:Paper board manufact
			3413:Articles of paper
Leather&products	28	5	3233:Leather products
			3241:Leather footwear
			3231:Tanning & products
Chemical fertlizer	29	23	3514:Fertilizer manufact
Pharmaceticals	30	24	3501:Medicines & drugs
			3502:Unani medicines
			3503:Ayurvedic medicines
			3504:Homeo etc medicines
Chemicals	31	5	3513:Compressed etc gas
			3515:Pesticides etc
			3516:Resins & plastic prod
			3519:Industrial chemicals
			3521:Paints & varnishes
			3522:Perfumes & cosmetics
			3523:Soap & detergents
			3524:Ploshes & waxes
			3526:Ink (all kind) product
			3527:Candle manufacturing
			3528:Tar & alketra
			3530:Match manufacturing
Petroleum products	32	25	3530:Petroleum refining
			3541 Petroleum products
Cement	33	26	3692:Cement manufacturing
Steel& basic products	34	4	3711:Iron & steel mills
			3712:Iron & steel foundry
			3713:Iron & steel rerolling
Metal products	35	4	3801:Cutlery
			3803:Razor & baldes
			3804:Metal furniture etc
			3807:Heating & cooking eqp
			3809:Aluminium utensils
			3815:Metal trunks
			3719:Iron & steel industry
			3802:Hand & edge tools
			3805:Structural metal prd
			3808:Wire & wire products
			3813:Metal barnets drums
			3814:Tin canes & wares
			3816:Bolts nuts rivets
			3817:Plumbering equipment
			3819:Fabricated metal prd
Machinery	36	4	3821:Engines & turbines
			3822:Agri machinery equip
			3823:Metal & wood machinery
			3824:Textile machinery
			3825:Industrial machinery
			3829:Machinery n.e.c.
			3827:Sewing machinery
			3832:Radio & television
			3833:Electrical appliance
			3834:Insulated wire cable
			3835:Electric bulbs & tubes
			3836:Batteries
Transport equipment	37	4	3839
			:Electric apparatus
			:Aeroplane spares
			:Railway carriages
			3841:Ship building & repair
			3844:Motor vehicles
			3845:M cycle/auto rickshaw
			3846:Cycles rickshaw etc

Table A5.18 (contd) :

Wood & wood products	38	3	3312:Plywood & products 3314:Hardboard & products 3321:Wooden furniture
Tobacco products	39	5	3141:Cigarette manufactng 3142:Cigars & cheroots 3145 :Zarda & products :Bidi making
Other industries	40	5	3612:China & ceramic ware 3222:Hat & caps 3421:Printing newspapers 3422:Printing & publishing 3425:Book bininding 3551:Tires & tubes 3552:Retrading tires & tube 3559:Rubber products 3569:Misc plastic product 3621:Glass manufacturing 3622:Glass products 3691:Bricks tiles etc 3693:Cement products 3695:Refractories manuf 3699:Non-metalic products 3862:Optical goods 3936:Pencils 3937:Pen & other products 3938:Umbrella & w sticks 3942:Bone crushing 3949:Other manuf industry
Urban house building	41	27	....Urban house building ....Rural house
Rural house building	42	28	building
Other construction	43	29	....Other construction
Electricity gen & dist	44	30	....Electricity gen & dist
Gas	45	31	....Gas production & dist
Trade services	46	32	....Trade services
Transport	47	33	....Transport services
Housing services	48	34	....Housing services
Health services	49	35	....Health services
Education services	50	36	....Education services
Public administration	51	37	....Public administration
Banking & insurance	52	38	....Banking & insurance
Professional services	53	39	....Professional services

Broad classification of sample industries

Industrial groups	Code	Sample size
Food & agro-based	1	11
Cotton & textiles	2	11
Timber & furniture	3	5
Engineering & electrical	4	13
Miscelleneous & service	5	18
All industries	-	58

Table A5.19: Leontief Matrix $(I - A)^{-1}$ for 39 sectors of Bangladesh economy

Sectors	Sectors 1 - 7						
1	1.182	.024	.004	.005	.153	.103	.148
2	.001	1.144	.003	.002	.002	.001	.001
3	.000	.002	1.019	.004	.011	.000	.000
4	.004	.010	.008	1.080	.024	.001	.004
5	.013	.067	.031	.040	1.143	.002	.007
6	.001	.000	.000	.000	.001	1.062	.000
7	.000	.100	.000	.000	.000	.000	1.004
8	.003	.000	.000	.000	.000	.000	.000
9	.000	.001	.000	.000	.000	.000	.000
10	.000	.001	.000	.001	.018	.000	.000
11	.000	.000	.000	.000	.000	.000	.000
12	.000	.000	.000	.000	.000	.000	.000
13	.000	.000	.000	.000	.000	.000	.000
14	.011	.000	.000	.000	.001	.001	.001
15	.001	.000	.000	.000	.000	.000	.000
16	.000	.000	.000	.000	.000	.000	.000
17	.001	.000	.000	.000	.000	.000	.000
18	.000	.000	.000	.000	.000	.000	.000
19	.014	.006	.455	.010	.058	.001	.003
20	.007	.000	.000	.000	.001	.001	.001
21	.004	.001	.000	.000	.002	.000	.000
22	.001	.009	.003	.003	.026	.000	.001
23	.017	.002	.000	.000	.005	.002	.016
24	.000	.001	.000	.000	.000	.000	.001
25	.003	.011	.008	.013	.011	.001	.006
26	.000	.000	.000	.000	.001	.000	.000
27	.000	.000	.000	.000	.000	.000	.000
28	.000	.000	.000	.000	.000	.000	.000
29	.006	.006	.008	.013	.012	.001	.008
30	.006	.026	.019	.016	.015	.007	.003
31	.003	.004	.005	.009	.014	.001	.002
32	.080	.255	.157	.518	.261	.030	.157
33	.017	.038	.031	.101	.029	.006	.050
34	.000	.000	.000	.000	.000	.000	.000
35	.000	.000	.000	.000	.000	.000	.000
36	.000	.000	.000	.000	.000	.000	.000
37	.001	.007	.007	.003	.004	.001	.003
38	.002	.020	.001	.009	.007	.004	.020
39	.005	.027	.003	.004	.011	.002	.010

Sectors 8 - 15							
.055	.052	.112	.049	.072	.038	.019	.005
.002	.001	.013	.002	.002	.002	.004	.001
.000	.000	.001	.000	.000	.000	.000	.000
.006	.001	.003	.001	.002	.001	.001	.001
.011	.002	.033	.003	.006	.002	.008	.001
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.001	.000	.000	.000	.000	.000
1.001	.000	.000	.000	.000	.000	.000	.000
.000	1.001	.000	.000	.000	.000	.000	.000
.000	.000	1.001	.000	.000	.000	.000	.000
.000	.000	.000	1.068	.000	.000	.000	.000
.000	.000	.000	.000	1.026	.000	.000	.000
.000	.000	.000	.000	.000	1.010	.000	.000
.001	.000	.001	.000	.001	.000	1.025	.000
.000	.000	.000	.000	.000	.000	.000	1.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.002	.002	.004	.001	.002	.001	.001	.002
.000	.000	.001	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.004	.000	.000	.000	.000	.000
.061	.004	.178	.010	.026	.004	.041	.000
.000	.000	.000	.000	.000	.000	.000	.000
.002	.003	.006	.001	.001	.003	.001	.002
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.001	.001	.004	.000	.001	.001	.001	.001
.003	.010	.009	.001	.001	.014	.002	.000
.006	.001	.026	.001	.003	.002	.004	.000
.130	.125	.183	.058	.143	.070	.091	.168
.018	.015	.032	.006	.014	.018	.007	.033
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.001	.001	.003	.000	.001	.001	.001	.002
.001	.001	.017	.001	.001	.001	.001	.001
.001	.001	.010	.000	.001	.001	.001	.001

Note : For definition of sectors, see Table A5.18

Table 5A.19 (contd) :

Sectors 16 - 23

.002	.055	.004	.001	.022	.005	.015	.023
.002	.002	.009	.001	.006	.002	.002	.031
.024	.000	.002	.000	.001	.000	.002	.003
.005	.002	.011	.003	.005	.004	.006	.008
.010	.006	.026	.004	.019	.036	.106	.166
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.001	.000	.001	.000	.005	.003
.000	.000	.000	.000	.367	.000	.001	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.001	.002	.003
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.001	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
1.002	.000	.000	.000	.000	.000	.000	.000
.000	1.012	.000	.000	.000	.000	.000	.000
.000	.000	1.008	.000	.000	.000	.000	.000
.015	.001	.009	1.042	.016	.011	.153	.010
.000	.000	.000	.000	1.000	.000	.002	.000
.000	.000	.000	.000	.000	1.000	.011	.000
.002	.000	.005	.000	.001	.019	1.071	.005
.020	.015	.000	.000	.022	.000	.001	1.001
.000	.000	.000	.000	.000	.000	.000	.000
.019	.005	.014	.002	.004	.007	.045	.006
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.003	.002	.002	.002	.002	.004	.009	.006
.004	.004	.004	.001	.002	.044	.040	.032
.007	.002	.001	.000	.004	.004	.011	.088
.115	.119	.170	.053	.219	.209	.336	.262
.029	.053	.033	.041	.036	.029	.071	.012
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.053	.001	.001	.015	.005	.002	.005	.002
.003	.005	.002	.001	.008	.003	.006	.005
.004	.002	.004	.001	.010	.003	.007	.008

Sectors 24 - 31

.047	.001	.008	.053	.009	.028	.004	.001
.001	.001	.021	.002	.001	.001	.001	.000
.005	.000	.006	.021	.022	.005	.000	.000
.008	.004	.015	.141	.110	.192	.015	.003
.300	.009	.054	.394	.063	.209	.028	.004
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.002	.000	.002	.000	.000	.000
.002	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.005	.000	.001	.006	.001	.003	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.022	.001	.006	.078	.616	.031	.002	.000
.005	.000	.000	.000	.000	.000	.000	.000
.001	.000	.000	.001	.000	.000	.000	.000
.008	.001	.002	.009	.002	.005	.002	.000
.002	.000	.000	.002	.000	.001	.000	.000
1.090	.000	.000	.000	.000	.000	.000	.000
.006	1.216	.008	.010	.004	.007	.127	.001
.000	.000	1.057	.015	.004	.009	.000	.000
.000	.000	.000	1.000	.000	.000	.000	.000
.000	.000	.000	.000	1.000	.000	.000	.000
.004	.003	.007	.006	.003	1.005	.010	.008
.008	.001	.022	.011	.003	.008	1.143	.003
.005	.001	.032	.007	.002	.006	.092	1.001
.319	.399	.374	.278	.148	.286	.180	.010
.023	.102	.023	.035	.040	.039	.050	.003
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.004	.002	.002	.003	.010	.002	.009	.000
.011	.003	.004	.004	.002	.004	.003	.001
.014	.006	.005	.005	.002	.003	.026	.002

Note : For definition of sectors, see Table A5.18

Table A5.19 (contd) :

Sectors 32 - 39

.001	.002	.003	.047	.002	.024	.006	.002
.001	.010	.000	.017	.002	.022	.001	.001
.000	.002	.005	.001	.000	.001	.001	.000
.000	.013	.017	.008	.001	.013	.003	.002
.003	.012	.023	.067	.007	.046	.032	.017
.000	.000	.000	.000	.000	.000	.000	.000
.000	.001	.000	.002	.000	.002	.000	.000
.000	.000	.000	.001	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.001	.000	.001	.001	.000
.000	.000	.000	.001	.000	.002	.000	.000
.000	.000	.000	.000	.000	.001	.000	.000
.000	.000	.000	.002	.000	.001	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.001	.000	.000
.000	.000	.000	.000	.000	.001	.000	.000
.000	.000	.000	.000	.000	.001	.000	.000
.000	.000	.000	.001	.000	.007	.003	.000
.002	.003	.071	.005	.001	.005	.003	.001
.000	.000	.000	.001	.000	.001	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.004	.001	.005	.002	.013	.003	.003
.000	.000	.000	.001	.000	.001	.000	.000
.000	.000	.001	.116	.000	.003	.027	.000
.000	.057	.001	.004	.001	.013	.004	.001
.000	.000	.001	.000	.000	.000	.000	.000
.000	.000	.035	.000	.000	.000	.000	.000
.000	.000	.109	.000	.000	.000	.000	.000
.000	.033	.001	.004	.002	.013	.008	.004
.002	.002	.001	.009	.003	.016	.005	.003
.000	.007	.001	.002	.000	.002	.001	.002
1.002	.095	.028	.093	.006	.079	.028	.013
.001	1.047	.006	.009	.002	.054	.015	.004
.000	.000	1.000	.000	.000	.000	.000	.000
.000	.000	.000	1.000	.000	.000	.005	.000
.000	.000	.000	.000	1.000	.000	.000	.000
.001	.015	.002	.001	.002	1.019	.014	.005
.005	.009	.053	.002	.000	.002	1.001	.005
.001	.004	.002	.003	.000	.040	.039	1.007

Note : For definition of sectors, see Table A5.18.

Table A5.20: Output multipliers for various sectors of Bangladesh economy

Sectors	Output multipliers	Rank
1	1.3825	20
2	1.7624	31
3	1.7643	32
4	1.8315	34
5	1.8110	33
6	1.2285	12
7	1.4480	24
8	1.3026	14
9	1.2216	11
10	1.6436	25
11	1.2039	8
12	1.3041	15
13	1.1685	6
14	1.2079	9
15	1.2202	10
16	1.3196	18
17	1.2892	13
18	1.3076	16
19	1.1659	5
20	1.7506	29
21	1.3860	22
22	1.9081	37
23	1.6753	27
24	1.8887	36
25	1.7528	30
26	1.6495	26
27	2.0827	39
28	2.0448	38
29	1.8455	35
30	1.6938	28
31	1.0371	3
32	1.0208	1
33	1.3172	17
34	1.3627	19
35	1.4068	23
36	1.0310	2
37	1.3839	21
38	1.2019	7
39	1.0721	4

Note : For definition of sectors, see Table A5.18

Table A5.21: Program [1] for construction of Leontief inverse matrix $(I - A)^{-1}$

```
MATRIX.
GET W
/FILE=’C:\SPSSWIN\SALIM\SALIM4.SAV’
/VARIABLES= VAR00001 TO VAR00071 VAR00072 TO VAR00078
/MISSING=ACCEPT
/SYSMIS=0.
COMPUTE R={1:53}.
COMPUTE C=T(R).
COMPUTE C1={54:58}.
COMPUTE C2={60:68}.
COMPUTE C3={54:57}.
COMPUTE A1=W(R,C).
COMPUTE A2=RSUM(A1).
COMPUTE A3=W(R,C1).
COMPUTE A4=RSUM(A3)-W(R,59).
COMPUTE A5={A2,A4}.
COMPUTE A6=RSUM(A5).
COMPUTE A7=MDIAG(A6).
COMPUTE A8=INV(A7).
COMPUTE B1=A6+W(R,59)-W(R,58)+W(R,77).
COMPUTE B2=MDIAG(B1).
COMPUTE B3=INV(B2).
COMPUTE B4=MDIAG(W(R,76))*B3*A1.
COMPUTE NCI=RSUM(B4).
COMPUTE PINCI=CSUM(B4).
COMPUTE PINCT=T(PINCI).
COMPUTE CIM=W(R,76)-NCI.
COMPUTE B5=MDIAG(W(R,74))*B3*A1.
COMPUTE TRNCI=RSUM(B5).
COMPUTE TRNCIU=CSUM(B5).
COMPUTE TTRNCIU=T(TRNCIU).
COMPUTE TRCI=W(R,74)-TRNCI.
COMPUTE MCI=W(R,71)-W(R,73)-W(R,74).
COMPUTE B6=MDIAG(MCI)*B3*A1.
COMPUTE MCNCI=RSUM(B6).
COMPUTE MNCIU=CSUM(B6).
COMPUTE TMNCIU=T(MNCIU).
COMPUTE MCCI=MCI-MCNCI.
COMPUTE B7=MDIAG(W(R,73))*B3*A1.
COMPUTE NCIT=RSUM(B7).
COMPUTE NCITU=CSUM(B7).
COMPUTE TNCITU=T(NCITU).
COMPUTE CIT=W(R,73)-NCIT.
COMPUTE B8=MDIAG(W(R,77))*B3*A1.
COMPUTE SCIT=RSUM(B8).
COMPUTE SCITU=CSUM(B8).
COMPUTE TSCITU=T(SCITU).
COMPUTE SCIF=W(R,77)-SCIT.
COMPUTE B9=B4+B5+B6+B7+B8.
COMPUTE B10=A1-B9.
COMPUTE TRADE=TMNCIU+MCCI.
COMPUTE TRANS=TTRNCIU+TRCI.
COMPUTE TAXNC=TNCITU+CIT.
COMPUTE SC=TSCITU.
COMPUTE TB10=T(B10).
COMPUTE TRAD1=TB10(R,46)+TRADE.
COMPUTE TRANS1=TB10(R,47)+TRANS.
COMPUTE TRADEC=MSUM(B10(R,46)).
COMPUTE TRANSC=MSUM(B10(R,47)).
COMPUTE TRADES=MSUM(TRADE).
COMPUTE TRANSS=MSUM(TRANS).
COMPUTE C4={1:45}.
COMPUTE R4=T(C4).
COMPUTE C5={48:53}.
COMPUTE R5=T(C5).
COMPUTE C6={60:67}.
COMPUTE B11={TB10(R,C4),TRAD1,TRANS1,TB10(R,C5)}.
```

(Table A5.21 contd):

```
COMPUTE TB11=T(B11).
COMPUTE WB=TB11.
COMPUTE W1=WB(R,1)+WB(R,2)+WB(R,15)+WB(R,18)+WB(R,19).
COMPUTE W2=WB(R,22)+WB(R,23)+WB(R,24)+WB(R,25)+WB(R,26).
COMPUTE W3=WB(R,38).
COMPUTE W4=WB(R,34)+WB(R,35)+WB(R,36)+WB(R,37).
COMPUTE W5=WB(R,28)+WB(R,31)+WB(R,39)+WB(R,40).
COMPUTE R6={3:14,16,17,20,21,27,29,30,32,33,41:53}.
COMPUTE TR6=T(R6).
COMPUTE W6={W1,W2,W3,W4,W5,WB(R,TR6)}.
COMPUTE W7=T(W6).
COMPUTE R7={1:39}.
COMPUTE C7=T(R7).
COMPUTE W8=W7(R7,1)+W7(R7,2)+W7(R7,15)+W7(R7,18)+W7(R7,19).
COMPUTE W9=W7(R7,22)+W7(R7,23)+W7(R7,24)+W7(R7,25)+W7(R7,26).
COMPUTE W10=W7(R7,38).
COMPUTE W11=W7(R7,34)+W7(R7,35)+W7(R7,36)+W7(R7,37).
COMPUTE W12=W7(R7,28)+W7(R7,31)+W7(R7,39)+W7(R7,40).
COMPUTE W13=W7(R7,TR6).
COMPUTE W14={W8,W9,W10,W11,W12,W13}.
COMPUTE W15=T(W14).
COMPUTE CW15=CSUM(W15).
COMPUTE TCW15=T(CW15).
COMPUTE IIN=CSUM(TB11).
COMPUTE INI=T(IIN).
COMPUTE W46=W(46,68)+TRADES.
COMPUTE W47=W(47,68)+TRANSS.
COMPUTE W68={W(R4,68);W46;W47;W(R5,68)}.
COMPUTE PRIN={W(R,C6),W68,PINCT,TAXNC,TSCITU}.
COMPUTE PRMIN=RSUM(PRIN).
COMPUTE GOUT1=INI+PRMIN.
COMPUTE W17=T(GOUT1).
COMPUTE W18=W17(1,1)+W17(1,2)+W17(1,15)+W17(1,18)+W17(1,19).
COMPUTE W19=W17(1,22)+W17(1,23)+W17(1,24)+W17(1,25)+W17(1,26).
COMPUTE W20=W17(1,38).
COMPUTE W21=W17(1,34)+W17(1,35)+W17(1,36)+W17(1,37).
COMPUTE W22=W17(1,28)+W17(1,31)+W17(1,39)+W17(1,40).
COMPUTE W23=W17(1,TR6).
COMPUTE W24={W18,W19,W20,W21,W22,W23}.
COMPUTE W25=T(W24).
COMPUTE GOUT=W25.
COMPUTE W26=MDIAG(GOUT).
COMPUTE W27=INV(W26).
COMPUTE IOCM=W15*W27.
COMPUTE W28=IDENT(39).
COMPUTE A=W28-IOCM.
COMPUTE B=INV(A).
COM CB=CSUM(B).
COM TCB=T(CB).
COM RCB=RNKORDER(TCB).
*COMPUTE XX1={C7,W15}.
*COMPUTE XX2={C7,IOCM}.
*COMPUTE XX3={C7,B}.
*COMPUTE XX={c7,tcb,rcb}.
COM X1=RSUM(W15).
COM XX={C7,X1,TCW15,W25}.
PRINT XX
/FORMAT="F18.3".
END MATRIX.
```

Table A5.21: (Contd) PROGRAM FOR CONSTRUCTION OF OUTPUT MULTIPLIERS.
FILE=PRG1.SPS TABLE A1.

```
MATRIX.
GET W
/FILE='A:\NISLAM.SAV'
/VARIABLES= VAR00001 TO VAR00075
/MISSING=ACCEPT
/SYSMIS=0.
COMPUTE R={1:53}.
COMPUTE C=T(R).
COMPUTE R1={1,2,15,18,19}.
COMPUTE W1=W(R,1)+W(R,2)+W(R,15)+W(R,18)+W(R,19).
COMPUTE R2={22,23,24,25,26}.
```

Table A5.21 (contd) :

```
COMPUTE W2=W(R,22)+W(R,23)+W(R,24)+W(R,25)+W(R,26).
COMPUTE R3={38}.
COMPUTE W3=W(R,38).
COMPUTE R4={34,35,36,37}.
COMPUTE W4=W(R,34)+W(R,35)+W(R,36)+W(R,37).
COMPUTE R5={28,31,39,40}.
COMPUTE W5=W(R,28)+W(R,31)+W(R,39)+W(R,40).
COMPUTE R6={3:14,16,17,20,21,27,29,30,32,33,41:53}.
COMPUTE TR6=T(R6).
COMPUTE W6={W1,W2,W3,W4,W5,W(R,TR6)}.
COMPUTE W7=T(W6).
COMPUTE R7={1:39}.
COMPUTE C7=T(R7).
COMPUTE W8=W7(R7,1)+W7(R7,2)+W7(R7,15)+W7(R7,18)+W7(R7,19).
COMPUTE W9=W7(R7,22)+W7(R7,23)+W7(R7,24)+W7(R7,25)+W7(R7,26).
COMPUTE W10=W7(R7,38).
COMPUTE W11=W7(R7,34)+W7(R7,35)+W7(R7,36)+W7(R7,37).
COMPUTE W12=W7(R7,28)+W7(R7,31)+W7(R7,39)+W7(R7,40).
COMPUTE W13=W7(R7,TR6).
COMPUTE W14={W8,W9,W10,W11,W12,W13}.
COMPUTE W15=T(W14).
COMPUTE RW15=RSUM(W15).
COMPUTE RRW15={RW15;0}.
COMPUTE CW15=CSUM(W15).
COMPUTE TCW15=T(CW15).
COMPUTE CC={C7;40}.
COMPUTE X={W15;CW15}.
COMPUTE C2={60:68}.
COMPUTE W16=RSUM(W(R,C2)).
COMPUTE W17=T(W16).
COMPUTE W18=W17(1,1)+W17(1,2)+W17(1,15)+W17(1,18)+W17(1,19).
COMPUTE W19=W17(1,22)+W17(1,23)+W17(1,24)+W17(1,25)+W17(1,26).
COMPUTE W20=W17(1,38).
COMPUTE W21=W17(1,34)+W17(1,35)+W17(1,36)+W17(1,37).
COMPUTE W22=W17(1,28)+W17(1,31)+W17(1,39)+W17(1,40).
COMPUTE W23=W17(1,TR6).
COMPUTE W24={W18,W19,W20,W21,W22,W23}.
COMPUTE W25=T(W24).
COMPUTE GOUT=W25+TCW15.
COMPUTE W26=MDIAG(GOUT).
COMPUTE W27=INV(W26).
COMPUTE IOCM=W15*W27.
COMPUTE W28=IDENT(39).
COMPUTE A=W28-IOCM.
COMPUTE B=INV(A).
COM CB=CSUM(B).
COM TCB=T(CB).
COM RCB=RNKORDER(TCB).
COMPUTE XX={C7,TCB,RCB}.
PRINT XX
/FORMAT="F24.4".
END MATRIX.

COMPUTE C1={54:58}.
COMPUTE W16=RSUM(W(R,C1))-W(R,59).
COMPUTE W17=T(W16).
OMPUTE W24={W18,W19,W20,W21,W22,W23}.
COMPUTE W25=T(W24).
COMPUTE XX={C7,W25}.
PRINT XX
/FORMAT="F24.4".
END MATRIX.

COMPUTE C3={54:57}.
COMPUTE XX={C7,RW15,TCW15}.
PRINT XX
/FORMAT="F24.4".
END MATRIX.
```

[1] The author gratefully acknowledges the help provided by M Salimullah of Strathclyde University in preparing the computer programmes.

Table A5.22: Associations between selected dependent variables and independent variable - INDUSTRIES and BUSINESS TYPES

[X2 = Chi squared value, S=Significant at 95% level, NS=Not significant,
- = Observations insufficient or not available]

DEPENDENT VARIABLE	Association with INDUSTRY Types (X2 value)			Association with BUSINESS Types (X2 value)		
	FLOOD TYPE			FLOOD TYPE		
	1	2	3	1	2	3
YEARS OF RUNNING BUSINESS	S	NS	NS	NS	NS	NS
AREA OF GROUND FLOOR	S	S	NS	NS	NS	S
AREA OF CEILING SPACE	S	NS	NS	NS	NS	NS
VALUE OF GROUND FLOOR	NS	S	NS	NS	NS	S
VALUE OF MACHINERY EQUIPMENT ETC	NS	S	NS	NS	S	NS
VALUE OF STOCK (INPUT + OUTPUT)	NS	S	NS	S	NS	NS
THRESHOLD HEIGHT-STOCK	NS	NS	NS	NS	-	NS
THRESHOLD HEIGHT-MACHINERY ETC	NS	NS	NS	S	NS	S
THRESHOLD DURATION-STOCK	S	NS	NS	NS	NS	NS
THRESHOLD DURATION-MACHINERY	NS	NS	NS	NS	NS	S
% OF STRUCTURAL DAMAGE RECOVERED	NS	NS	NS	S	NS	NS
TOTAL TIME TO RECOVER	NS	NS	NS	NS	NS	NS
TOTAL COST OF CLEAN UP	NS	NS	NS	S	NS	NS
IF BELIEVED MESSAGE OF WARNING	-	NS	-	-	NS	-
LEAD TIME	-	NS	NS	NS	NS	NS
PERCEIVED HOURS BEFORE FLOOD ENTERED	NS	NS	NS	NS	NS	NS
HRS BETW WATER ENTERED TOWN AND PROPERTY	NS	NS	NS	NS	NS	NS
FREQUENCY OF FLOODING	NS	NS	NS	NS	NS	NS
DEPTH OF FLOODING	NS	NS	NS	NS	NS	NS
DURATION OF FLOODING	NS	NS	NS	NS	NS	NS
% DAMAGE TO STOCK DUE TO INUNDATION	-	S	S	-	NS	NS
% DAMAGE TO STOCK DUE TO VELOCITY	-	NS	NS	-	NS	NS
% DAMAGE TO STOCK DUE TO STORM	-	-	NS	-	-	NS
% DAMAGE TO STOCK DUE TO SALT	-	-	NS	-	-	NS
TOTAL STRUCTURAL DAMAGE-TOTSTDAM	NS	NS	NS	S	NS	NS
DAMAGE TO MACHINERY EQUIPMENT-DAMMC	NS	S	S	NS	NS	S
DAMAGE TO STOCK (INPUT+OUTPUT)-DAMSTCK	NS	NS	NS	NS	NS	NS
IF MOVED MERCHANDISE TO SAFER PLACE	-	NS	NS	-	NS	NS
VALUE OF MACHINERY ETC REMOVED-MOVE1	NS	NS	-	NS	S	NS
VALUE OF STOCK ETC REMOVED-MOVE2	S	NS	-	S	NS	S

Table A5.22 (contd):

DEPENDENT VARIABLES	Association with INDUSTRY Types (X2 value)			Association with BUSINESS Types (X2 value)		
	FLOOD TYPE			FLOOD TYPE		
	1	2	3	1	2	3
VALUE OF DAMAGES(MACHINERY)AVOIDED-DAMAVOD1	NS	NS	-	NS	NS	-
VALUE OF DAMAGES(STOCK) AVOIDED-DAMAVOD2	NS	NS	-	S	NS	S
POTENTIAL DAMAGES TO MACHINERY EQUIPMENT	NS	S	S	NS	NS	S
POTENTIAL DAMAGES TO STOCK	S	NS	NS	S	NS	NS
AVERAGE MONTHLY OUTPUT	S	NS	NS	NS	NS	S
VALUE ADDED/TURNOVER LOSS	NS	S	NS	NS	NS	NS
TOTAL EMPLOYMENT	S	S	NS	NS	NS	NS
GROSS INCOME AS % OF OUTPUT/TURNOVER	S	NS	S	NS	NS	S
DAYS OF COMPLETE CLOSURE	NS	S	NS	NS	NS	NS
DAYS OF PARTIAL CLOSURE	NS	S	NS	NS	S	NS
AVERAGE PRODUCTION DURING PARTIAL CLOSURE	S	S	S	NS	NS	NS
% OF LOST PRODUCTION RECOVERED	S	NS	NS	NS	-	NS
% LOST OUTPUT TAKEN UP BY TOWN UNITS	NS	NS	S	NS	NS	NS
% LOST OUTPUT TAKEN UP BY REGIONAL UNITS	NS	NS	NS	NS	NS	NS
% LOST OUTPUT TAKEN UP BY COUNTRY UNITS	NS	NS	S	NS	NS	NS
% LOST OUTPUT NOT TAKEN UP BY ANY UNITS	NS	NS	NS	NS	NS	NS
MODE OF TRANSPORT OF OUTPUT	-	-	NS	-	-	NS
MODE OF TRANSPORT OF INPUT	-	-	NS	-	-	NS
IF CAN USE WATERWAYS IF ROADS SUBMERGED	NS	-	NS	NS	S	NS
MAIN PLACE OF SELLING OUTPUT	NS	NS	S	NS	NS	NS
MAIN PLACE OF BUYING INPUT	NS	S	NS	S	NS	NS
EXTENT BUYERS DEPENDENT ON YOU	NS	NS	NS	NS	S	NS
EXTENT YOU ARE DEPENDENT ON BUYERS	NS	S	NS	NS	NS	NS
NORMAL STOCK OF OUTPUT (DAYS)	NS	NS	NS	S	NS	NS
%INCOME OF UNIT COMPARED TO PRE-FLOOD LEVEL	NS	NS	NS	NS	NS	NS
%DEMAND OF UNIT COMPARED TO PRE-FLOOD LEVEL	NS	NS	NS	NS	NS	NS
%EMPLOYMENT COMPARED TO PRE-FLOOD LEVEL	NS	NS	NS	NS	NS	S
%WAGE RATES COMPARED TO PRE-FLOOD LEVEL	NS	NS	NS	NS	NS	S
%OUTPUT PRICE COMPARED TO PRE-FLOOD LEVEL	NS	NS	-	S	S	S
STRUCTURAL DAMAGE AS % OF VALUE - DAMPROP1	NS	NS	NS	NS	NS	NS
MACHINERY ETC DAMAGE AS % OF VALUE-DAMPROP2	NS	NS	NS	NS	NS	S
STOCK DAMAGE AS % OF VALUE - DAMPROP3	NS	NS	NS	S	NS	NS

Note ; Flood type 1 - Major river flood (Tangail)
2 - Flash flood (Bahubal)
3 - Tidal flood (Khatunganj)

Table A5.23: Labels of selected variables under study of association

Dependent variables	Label	Independent Variables	Label
TOTSTDAM	TOTAL DAMAGE TO ALL STRUCTURES	AREAC	AREA OF CEILING UNDER ROOF
DAMMC	ACTUAL DAMAGE TO MACHINERY EQUIPMENT	AREAG	AREA OF GROUND FLOOR
POTMC	POTENTIAL DAMAGE TO MACHINERY EQUIPMENT	FREQ	FREQUENCY OF FLOODING
DAMSTCK	ACTUAL DAMAGE TO STOCK (OUTPUT+INPUT)	BELIEVE	IF BELIEVED MESSAGE OF WARNING GIVEN
POTSTCK	POTENTIAL DAMAGE TO STOCK (OUTPUT+INPUT)	LEAD	TIME BETW WARNING GIVEN & WATER ENTERED IN PROPERTY
MOVE1	VALUE OF EXPOSED MACHINERY ETC MOVED	PERLEAD	TIME BETW PERCEIVED (ANTICIPATING FOR SURE) & WATER ENTERED IN PROPERTY
MOVE2	VALUE OF EXPOSED STOCK MOVED	ENTER	TIME BETW WATER ENTERED TOWN & IN PROPERTY
DAMAVOD1	DAMAGE OF MACHINERY AVOIDED BY REMOVAL	VALBDG	VALUE OF GROUND FLOOR BUILDING
DAMAVOD2	DAMAGE OF STOCK AVOIDED BY REMOVAL	VALMC	VALUE OF MACHINERY EQUIPMENT
DAMPROP1	STRUCTURAL DAMAGE AS % OF VALUE OF BUILDING	VALSTCK	VALUE OF STOCK(INPUT+STOCK)
DAMPROP2	POTMC AS % OF VALUE OF MACHINERY EQUIPMENT	YRS	YEARS OF RUNNING BUSINESS
DAMPROP3	POTSTCK AS % OF VALUE OF STOCK	DEPTH	DEPTH OF FLOODING
VALOSS	LOSS OF VALUE ADDED IN INDUSTRIES	DUR	DURATION OF FLOODING
GROSMR	LOSS OF GROSS MARGIN IN BUSINESS	EMPL	TOTAL NUMBER OF EMPLOYED PERSONS

Table A5.24: Associations among selected dependent and independent variables

[X2 = CHI SQUARED VALUE; S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]

Flood type : Major river flood : INDUSTRIES

Dependent variable	x2- Association with independent variables													
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	-	S	NS	-	-	S	NS	S	-	-	-	NS	NS	S
DAMMC	NS	S	NS	-	-	NS	NS	-	S	-	NS	NS	NS	S
POTMC	NS	S	NS	-	-	NS	NS	-	S	-	NS	NS	NS	S
DAMSTCK	NS	S	NS	-	-	NS	NS	-	-	S	NS	NS	NS	S
POTSTCK	NS	S	NS	-	-	NS	NS	-	-	S	NS	NS	NS	S
MOVE1	NS	S	NS	-	-	S	NS	-	S	-	S	NS	NS	S
MOVE2	NS	S	NS	-	-	NS	NS	-	-	S	NS	NS	NS	S
DAMAVOD1	S	S	NS	-	-	NS	S	-	S	-	S	NS	NS	S
DAMAVOD2	S	S	NS	-	-	NS	NS	-	-	S	NS	NS	NS	S
DAMPROP1	-	NS	NS	-	-	NS	NS	S	-	-	NS	NS	NS	NS
DAMPROP2	S	NS	S	-	-	NS	NS	-	S	-	NS	NS	NS	NS
DAMPROP3	NS	NS	NS	-	-	NS	NS	-	-	NS	NS	NS	NS	NS
VALOSS	-	S	NS	-	-	-	-	-	-	S	NS	NS	NS	S

Flood type : Flash flood : INDUSTRIES

TOTSTDAM	-	NS	NS	NS	S	S	NS	S	-	-	-	NS	NS	NS
DAMMC	NS	S	S	NS	NS	NS	NS	-	S	-	NS	S	NS	NS
POTMC	NS	S	S	NS	NS	NS	NS	-	S	-	NS	S	NS	NS
DAMSTCK	NS	NS	NS	NS	NS	NS	NS	-	-	S	NS	S	NS	S
POTSTCK	NS	NS	NS	NS	NS	NS	NS	-	-	S	NS	NS	NS	NS
MOVE1	NS	NS	NS	NS	NS	NS	-	-	NS	-	NS	S	S	S
MOVE2	NS	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	NS	NS
DAMAVOD1	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS	NS	NS	NS
DAMAVOD2	S	NS	NS	NS	NS	NS	NS	-	-	S	NS	NS	NS	NS
DAMPROP1	-	NS	NS	NS	S	NS	NS	NS	-	-	NS	S	NS	S
DAMPROP2	NS	NS	NS	NS	S	NS	NS	-	NS	-	NS	NS	NS	NS
DAMPROP3	NS	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	S	NS
VALOSS	-	S	NS	-	-	-	-	-	-	NS	NS	S	NS	S

Note: For definition of variables, see Table A5.23.

Table A5.24 (contd):

[X2 = CHI SQUARED VALUE; S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]

Flood type : Tidal flood : INDUSTRIES

Dependent variable	X2 Association with independent variables													
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	-	S	S	NS	NS	NS	NS	S	-	-	-	NS	S	S
DAMMC	S	S	S	NS	NS	NS	NS	-	S	-	NS	NS	S	S
POTMC	NS	S	NS	NS	S	NS	S	-	S	-	NS	NS	S	S
DAMSTCK	NS	S	NS	NS	NS	NS	NS	-	-	S	S	NS	S	NS
POTSTCK	NS	S	NS	NS	NS	NS	NS	-	-	S	S	NS	S	NS
MOVE1	NS	NS	NS	NS	NS	NS	NS	-	NS	-	NS	NS	NS	NS
MOVE2	NS	NS	NS	S	S	S	NS	-	-	NS	S	NS	S	S
DAMAVOD1	NS	NS	NS	NS	NS	NS	NS	-	-	-	NS	NS	NS	NS
DAMAVOD2	NS	NS	NS	S	S	S	NS	-	-	NS	S	NS	S	S
DAMPROP1	-	S	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	S
DAMPROP2	NS	NS	NS	NS	NS	NS	NS	-	S	-	NS	NS	NS	S
DAMPROP3	NS	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	NS	NS
VALOSS	-	S	S	-	-	-	-	-	-	S	NS	NS	NS	S

Note: For definition of variables, see Table A5.23.

Table A5.25: Associations among selected dependent and independent variables

[X2 = CHI SQUARED VALUE; S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]

Flood type : Major river flood : BUSINESS

Dependent variable	X2 Association with independent variables													
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	-	NS	NS	-	-	NS	S	S	-	-	-	NS	S	NS
DAMMC	NS	NS	NS	-	-	NS	NS	-	NS	-	NS	NS	NS	NS
POTMC	NS	NS	NS	-	-	NS	NS	-	S	-	NS	NS	NS	NS
DAMSTCK	NS	NS	NS	-	-	NS	NS	-	-	S	NS	NS	S	NS
POTSTCK	NS	NS	NS	-	-	NS	NS	-	-	S	NS	NS	NS	NS
MOVE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MOVE2	NS	NS	NS	-	-	NS	NS	-	-	S	NS	NS	NS	NS
DAMAVOD1	NS	NS	NS	-	-	NS	NS	-	NS	-	NS	NS	NS	NS
DAMAVOD2	NS	S	S	-	-	NS	NS	-	-	S	S	S	NS	NS
DAMPROP1	-	NS	NS	-	-	S	S	NS	-	-	NS	NS	NS	NS
DAMPROP2	NS	NS	NS	-	-	S	NS	-	NS	-	NS	NS	NS	NS
DAMPROP3	NS	NS	NS	-	-	NS	NS	-	-	NS	NS	NS	NS	NS
GROSMR	-	NS	NS	-	-	-	-	-	-	S	NS	NS	NS	NS

Flood type : Flash flood : BUSINESS

TOTSTDAM	-	NS	-	NS	NS	NS	S	NS	-	-	-	NS	NS	NS
DAMMC	S	NS	-	NS	NS	NS	NS	-	NS	-	S	NS	NS	NS
POTMC	S	NS	-	NS	NS	NS	NS	-	NS	-	S	NS	NS	NS
DAMSTCK	S	NS	-	NS	NS	NS	NS	-	-	S	NS	NS	NS	NS
POTSTCK	S	NS	-	S	S	S	S	-	-	S	NS	NS	NS	NS
MOVE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MOVE2	NS	S	-	NS	S	S	S	-	-	NS	NS	NS	NS	NS
DAMAVOD1	NS	NS	-	NS	NS	NS	NS	-	NS	-	NS	NS	NS	S
DAMAVOD2	NS	S	-	S	NS	S	NS	-	-	S	NS	NS	NS	NS
DAMPROP1	-	S	-	NS	NS	S	NS	S	-	-	NS	NS	NS	NS
DAMPROP2	NS	NS	-	NS	NS	NS	NS	-	NS	-	NS	NS	NS	NS
DAMPROP3	NS	S	-	NS	S	NS	S	-	-	NS	NS	NS	NS	NS
GROSMR	-	NS	-	-	-	-	-	-	-	NS	NS	NS	NS	S

Note: For definition of variables, see Table A5.23.

Table A5.25 (contd):

[X2 = CHI SQUARED VALUE; S= SIGNIFICANT AT 95% LEVEL; NS=NOT SIGNIFICANT;
- = OBSERVATIONS INSUFFICIENT OR NOT AVAILABLE OR TEST NOT LOGICAL]

Flood type : Tidal flood : BUSINESS

Dependent variable	X2 Association with independent variables													
	AREAC	**AREAG**	**FREQ**	**BELIEVE**	**LEAD**	**PERLEAD**	**ENTER**	**VALBDG**	**VALMC**	**VALSTCK**	**YRS**	**DEPTH**	**DUR**	**EMPL**
TOTSTDAM	-	NS	NS	-	NS	S	S	NS	-	-	-	S	NS	S
DAMMC	NS	NS	NS	-	NS	S	NS	-	NS	-	NS	NS	NS	S
POTMC	NS	NS	NS	-	NS	S	S	-	NS	-	NS	NS	NS	S
DAMSTCK	NS	S	NS	-	NS	NS	NS	-	-	S	S	S	NS	S
POTSTCK	NS	S	NS	-	NS	NS	S	-	-	S	NS	S	NS	NS
MOVE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MOVE2	NS	NS	NS	-	NS	S	NS	-	-	NS	NS	NS	S	NS
DAMAVOD1	NS	NS	NS	-	NS	NS	NS	-	NS	-	NS	NS	NS	NS
DAMAVOD2	NS	NS	NS	-	NS	S	NS	-	-	NS	NS	NS	S	NS
DAMPROP1	-	NS	S	-	S	S	NS	NS	-	-	NS	S	NS	S
DAMPROP2	NS	NS	NS	-	NS	S	S	-	NS	-	NS	NS	S	NS
DAMPROP3	NS	NS	NS	-	NS	NS	NS	-	-	NS	S	NS	NS	NS
GROSMR	-	NS	NS	-	-	-	-	-	-	NS	NS	NS	NS	NS

Note: For definition of variables, see Table A5.23.

Table A5.26: Correlation coefficients between selected key flood variables

Flood type: major river flood : INDUSTRIES

Correlations with

	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER	VALBDG
TOTSTDAM	-	.46**	.02	-	-	-.31	-.13	.64**
DAMMC	-.07	.31	.05	-	-	-.29	-.10	-
POTMC	-.04	.26	.01	-	-	-.30	-.10	-
DAMSTCK	-.07	.44**	.15	-	-	-.29	-.04	-
POTSTCK	-.08	.34*	.26	-	-	-.26	.07	-
MOVE1	-.03	.73**	.00	-	-	-.36*	-.11	-
MOVE2	-.08	.61**	.22	-	-	-.32*	.09	-
DAMAVOD1	-.03	.15	-.05	-	-	-.32	-.09	-
DAMAVOD2	-.09	.21	.34*	-	-	-.20	.17	-
DAMPROP1	-	-.10	.07	-	-	-.18	-.12	-.16
DAMPROP2	.20	-.22	.02	-	-	.04	-.18	-
DAMPROP3	.01	-.13	.03	-	-	.18	.29	-
VALOSS	-	.28	.09	-	-	-	-	-

Correlations with

	VALMC	VALSTCK	YRS	DEPTH	DUR	EMP1
TOTSTDAM	-	-	-	-.08	-.11	.48**
DAMMC	.80**	-	-.03	-.12	-.16	.59**
POTMC	.84**	-	-.07	-.13	-.14	.54**
DAMSTCK	-	.96**	.02	.02	-.17	.73**
POTSTCK	-	.89**	.01	.11	-.14	.80**
MOVE1	.32	-	-.03	-.07	-.13	.54**
MOVE2	-	.84**	.09	-.01	-.20	.76**
DAMAVOD1	.83**	-	-.12	-.14	-.11	.32
DAMAVOD2	-	.75**	-.00	.19	-.09	.80**
DAMPROP1	-	-	-.04	.24	.48**	.01
DAMPROP2	-.22	-	.10	.20	.12	-.22
DAMPROP3	-	-.20	.14	.06	.05	.05
VALOSS	-	.74**	-.03	-.01	-.15	.61**

Note :

For definitions of variables, see Table A5.23.

** represents two-tailed significance at 99%, and * at 95% level.

The variables Believe and Lead are not applicable as no formal warning was given in case of major river flood area.
'-' Those for which correlations are not logical or not estimated.

Table A5.27: Correlation coefficients between selected key flood variables

Flood type : Flash flood :INDUSTRIES

	Correlations with						
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER
TOTSTDAM	-	-.09	-.26	-.07	-.41	.05	.06
DAMMC	-.07	.01	.06	-.23	-.12	-.23	-.06
POTMC	-.07	.02	.06	-.22	-.12	-.23	-.06
DAMSTCK	-.05	-.04	-.14	-.29	.16	-.31	-.27
POTSTCK	-.03	-.01	-.14	-.28	.18	-.31	-.29
MOVE1	-.01	.39	.08	.25	.17	.23	.01
MOVE2	.08	.24	-.02	.04	.18	-.07	-.12
DAMAVOD1	-	.55**	.09	.39	.29	.25	.02
DAMAVOD2	.21	.25	-.01	.09	.17	-.05	-.16
DAMPROP1	-.10	-.21	-.02	-.03	-.38	.05	.31
DAMPROP2	-.08	-.11	.10	-.16	-.33	-.11	-.11
DAMPROP3	.00	.04	-.36	-.17	-.09	.06	-.19
VALLOS	-	.08	-.16	-	-	-	-

	Correlations with						
	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	-.02	-	-	-	.59**	.33	.02
DAMMC	-	.91**	-	-.01	.14	-.10	.76**
POTMC	-	.91**	-	-.02	.14	-.09	.76**
DAMSTCK	-	-	.56**	-.09	.50*	-.03	.51*
POTSTCK	-	-	.55**	-.09	.49*	-.01	.52*
MOVE1	-	.07	-	-.08	.21	.33	-.02
MOVE2	-	-	-.08	-.02	-.19	.07	.09
DAMAVOD1	-	-.02	-	-.08	-.01	.14	-.07
DAMAVOD2	-	-	-.10	.07	-.15	.15	.06
DAMPROP1	-.33	-	-	-.36	.26	.41	-.15
DAMPROP2	-	.68**	-	-.16	.11	-.01	.61**
DAMPROP3	-	-	-.20	-.03	.53*	.42	-.10
VALLOS	-	-	.87**	-.04	.39	-.13	.75**

Note :

For definitions of variables, see Table A5.23.

** represents two-tailed significance at 99% level, and * at 95% level.

'-' Those for which correlations are not logical or not estimated.

Table A5.28: Correlation coefficients between selected key flood variables

Flood type : Tidal flood :INDUSTRIES

	Correlations with						
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER
TOTSTDAM	-	.81**	.29	.12	.24	.34	-.18
DAMMC	-.23	.51*	.18	.09	.05	.09	-.21
POTMC	-.22	.57**	.21	.09	.09	.09	-.21
DAMSTCK	-.08	.36	-.05	-.07	.03	.19	-.12
POTSTCK	-.10	.54**	-.13	.42	-.09	.93**	-.09
MOVE1	-	-	-	-	-	-	-
MOVE2	-.08	.48*	-.13	.52*	-.12	1.00**	-.05
DAMAVOD1	-	-	-	-	-	-	-
DAMAVOD2	-.08	.48*	-.13	.52*	-.12	1.00**	-.05
DAMPROP1	-	-.32	.50*	.08	.08	-.12	.04
DAMPROP2	-.04	-.15	.46*	-.27	.10	-.19	-.12
DAMPROP3	.01	.20	.15	.01	-.09	.14	-.20
VALOSS	-	.48*	.30	-	-	-	-

	Correlations with						
	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	.77**	-	-	-	.29	-.42*	.70**
DAMMC	-	.52*	-	.32	.04	-.25	.55**
POTMC	-	.53*	-	.39	.06	-.24	.59**
DAMSTCK	-	-	.44*	.19	.22	-.46*	.20
POTSTCK	-	-	.99**	-.14	.38	-.45*	.36
MOVE1	-	-	-	-	-	-	-
MOVE2	-	-	.96**	-.24	.35	-.32	.33
DAMAVOD1	-	-	-	-	-	-	-
DAMAVOD2	-	-	.96**	-.24	.35	-.32	.33
DAMPROP1	-.32	-	-	-.11	.31	.10	-.32
DAMPROP2	-	-.37	-	-.00	.01	.09	-.10
DAMPROP3	-	-	.20	.06	.60**	-.08	.20
VALOSS	-	-	.16	.47*	.11	-.07	.34

Note :

For definitions of variables, see Table A5.23.

** represents two-tailed significance at 99% level, and * at 95% level.

'-' Those for which correlations are not logical or not estimated.

Table A5.29: Correlation coefficients between selected key flood variables

Flood type : Major river flood :BUSINESS

	Correlations with						
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER
TOTSTDAM	-	.47*	-.13	-	-	.10	-.14
DAMMC	-.16	-.13	-.13	-	-	-.02	.02
POTMC	-.20	-.02	-.16	-	-	-.00	-.09
DAMSTCK	-.19	.53**	.04	-	-	.01	.03
POTSTCK	-.11	.68**	-.07	-	-	-.07	-.04
MOVE1	-	-	-	-	-	-	-
MOVE2	-.08	.65**	-.08	-	-	-.01	-.05
DAMAVOD1	-.20	.04	-.17	-	-	.05	-.14
DAMAVOD2	-.09	.67**	-.09	-	-	-.08	-.05
DAMPROP1	-	-.08	.11	-	-	.12	-.28
DAMPROP2	-.15	-.37*	.23	-	-	-.20	-.13
DAMPROP3	.04	.06	.09	-	-	.03	.06
GROSMR	-	.36	-.11	-	-	-	-

	Correlations with						
	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	.50**	-	-	-	-.03	.30	.30
DAMMC	-	.65**	-	.25	-.20	.02	.31
POTMC	-	.35	-	.02	-.18	.23	.24
DAMSTCK	-	-	.64**	.21	.11	.14	.32
POTSTCK	-	-	.82**	.11	-.14	.10	.51**
MOVE1	-	-	-	-	-	-	-
MOVE2	-	-	.83**	.13	-.25	.11	.53**
DAMAVOD1	-	.25	-	-.12	-.15	.29	.26
DAMAVOD2	-	-	.81**	.08	-.18	.09	.51**
DAMPROP1	-.13	-	-	-.09	.03	.10	-.08
DAMPROP2	-	-.17	-	-.15	.15	.05	-.02
DAMPROP3	-	-	-.16	-.16	.07	.02	-.00
GROSMR	-	-	.69**	-.18	.23	.22	.28

Note :

For definitions of variables, see Table A5.23.

** represents two-tailed significance at 99% level, and * at 95%% level.

The variables Believe and Lead are not applicable as no formal warning was given in case of major river flood area.

'-' Those for which correlations are not logical or not estimated.

Table A5.30: Correlation coefficients between selected key flood variables

Flood type : Flash flood : BUSINESS

Correlations with

	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER
TOTSTDAM	-	.09	-	.18	.29	.03	-.05
DAMMC	.50*	-.09	-	.24	.12	.18	.01
POTMC	.21	.37	-	.45	.30	.33	.12
DAMSTCK	-.15	.27	-	.33	.12	.12	.16
POTSTCK	-.04	.51*	-	.57*	.26	.44*	.31
MOVE1	-	-	-	-	-	-	-
MOVE2	-.07	.56**	-	.46*	.25	.49*	.28
DAMAVOD1	-.16	.56**	-	.26	.12	.18	.07
DAMAVOD2	.03	.52*	-	.57*	.27	.51*	.32
DAMPROP1	-	-.26	-	-.01	-.06	-.09	-.24
DAMPROP2	-.10	-.07	-	.09	.47*	-.23	-.12
DAMPROP3	-.00	.10	-	.41	.28	.19	.13
GROSMR	-	-.13	-	-	-	-	-

Correlations with

	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	.07	-	-	-	-.25	.03	.32
DAMMC	-	.32	-	.34	-.31	-.03	.04
POTMC	-	.36	-	.25	-.14	-.01	.46*
DAMSTCK	-	-	.41	.02	.06	.12	.35
POTSTCK	-	-	.64**	.08	-.07	.04	.51*
MOVE1	-	-	-	-	-	-	-
MOVE2	-	-	.76**	-.05	-.11	-.11	.51*
DAMAVOD1	-	.25	-	-.06	.13	-.05	.44*
DAMAVOD2	-	-	.61**	.09	-.12	-.02	.47*
DAMPROP1	-.24	-	-	-.25	-.25	.02	-.13
DAMPROP2	-	-.46*	-	.06	-.02	.10	.34
DAMPROP3	-	-	-.17	-.00	.13	-.15	.18
GROSSMR	-	-	.12	-.18	-.04	-.09	.56

Note :

For definitions of variables, see Table A5.23.

** represents two-tailed significance at 99% level and * at 95% level.

The variable, Freq has not shown any variation in this area.
'-' Those for which correlations are not logical or not estimated.

Table A5.31: Correlation coefficients between selected key flood variables

Flood type : Tidal flood :BUSINESS

	correlations with						
	AREAC	AREAG	FREQ	BELIEVE	LEAD	PERLEAD	ENTER
TOTSTDAM	-	.34	.18	.16	.17	-.18	.01
DAMMC	-.11	-.08	.02	.10	.14	-.12	-.13
POTMC	-.06	.02	.02	.15	.13	-.13	-.14
DAMSTCK	.10	.72**	-.07	-.04	.14	-.08	-.09
POTSTCK	.10	.72**	-.07	.00	.14	-.03	-.10
MOVE1	-	-	-	-	-	-	-
MOVE2	-.07	-.09	-.03	.55**	.04	.68**	-.11
DAMAVOD1	-.16	.05	.24	.19	.02	-.04	-.06
DAMAVOD2	-.05	-.10	-.06	.56**	.05	.73**	-.11
DAMPROP1	-	-.09	.49*	.11	.35	-.19	.06
DAMPROP2	-.15	.12	.13	.32	-.01	-.14	-.03
DAMPROP3	-.10	.40	.06	.25	.21	.13	-.11
GROSMR	-	.40	.13	-	-	-	-
	Correlations with						
	VALBDG	VALMC	VALSTCK	YRS	DEPTH	DUR	EMPL
TOTSTDAM	.22	-	-	-	.57**	.51*	.71**
DAMMC	-	.61**	-	-.18	.04	.18	.05
POTMC	-	.53*	-	-.14	.11	.19	.14
DAMSTCK	-	-	.63**	.21	.31	-.05	.66**
POTSTCK	-	-	.63**	.22	.30	-.07	.66**
MOVE1	-	-	-	-	-	-	-
MOVE2	-	-	-.03	.07	-.12	-.26	-.06
DAMAVOD1	-	-.06	-	-.15	.19	.08	.12
DAMAVOD2	-	-	-.04	.09	-.15	-.29	-.08
DAMPROP1	-.30	-	-	-.04	.68**	.46*	.33
DAMPROP2	-	-.11	-	-.04	.33	.24	.30
DAMPROP3	-	-	.03	.20	.22	-.11	.40
GROSMR	-	-	.33	.03	.30	.35	.73**

Note :

For definitions of variables, see Table A5.23.

** represents two-tailed significance at 99%, and * at 95% level.

'-' Those for which correlations are not logical or not estimated.

Table A5.32: Estimates of the magnitude of damage-contributing (other than Depth and Duration) factors in total damage

Industries: Bahubal (Flash flood) and Khatunganj (Tidal flood)

Damage components /Industry type	Flood type					
	Flash flood		Tidal flood			
	% of damage caused due to		% of damage caused due to			
	Inundation	Velocity	Inundation	Velocity	Storm	Salinity
Structures						
Food & agro-based	62	38	18	26	48	8
Cotton & textiles	100	-	23	31	38	8
Timber & furniture	72	28	8	28	62	2
Engineering&electrical	83	17	9	22	67	2
Miscellaneous& service	70	30	8	21	70	1
- ALL	74	26	13	25	57	5
Machinery						
Food & agro-based	77	23	51	12	1	30
Cotton & textiles	100	-	22	5	3	70
Timber & furniture	85	15	28	20	-	52
Engineering&electrical	84	16	25	10	2	63
Miscellaneous& service	84	16	44	8	3	45
- ALL	83	17	38	10	2	50
Stock						
Food & agro-based	86	14	68	18	3	11
Cotton & textiles	100	-	48	3	3	46
Timber & furniture	58	42	18	63	17	2
Engineering&electrical	87	13	26	8	1	65
Miscellaneous& service	77	23	66	14	6	14
- ALL	79	21	52	17	5	26

Note
: The gross estimates provided by respondents have ignored interactions.
: Average percentage represented weighted average, weights being the damage value of relevant components of respective properties.
:- Type of industries not available in the area, or data not available

Table A5.33: Estimates of the magnitude of damage-contributing (other than Depth and Duration) factors in total damage

Business : Bahubal (Flash flood) and Khatunganj (Tidal flood)

Damage components /Business group	Flood type					
	Flash flood		Tidal flood			
	% of damage caused due to		% of damage caused due to			
	Inundation	Velocity	Inundation	Velocity	Storm	Salinity
Structures						
Food & grocery	69	31	22	23	35	20
Cloth & footwear	84	16	12	8	50	30
Drugs & chemicals	65	35	20	17	46	17
Electrical&electronics	-	-	-	-	-	-
Motor/cycle parts	78	22	20	40	40	-
Construction materials	77	23	9	20	24	47
Miscellaneous	65	35	5	33	62	-
- ALL	72	28	17	23	39	21
Stock						
Food & grocery	92	8	59	23	5	13
Cloth & footwear	97	3	33	10	2	53
Drugs & chemicals	97	3	72	8	3	17
Electrical&electronics	-	-	30	10	-	60
Motor/cycle parts	82	18	60	20	10	10
Construction materials	90	10	36	13	3	48
Miscellaneous	77	23	20	13	13	54
- ALL	91	9	50	17	5	28

Note

: The gross estimates provided by respondents have ignored interactions.

: Average percentage represented weighted average, weights being the damage value of relevant components of respective properties.

:- Type of business not available in the area, or information not available

Table A5.34: Flood variables under study and inherent assumptions

Key flood damage variables	Assumptions
<u>A Flood Characteristics</u>	
1 Depth	At various Durations Velocity, Silts, Discharge assumed constant. (Storm, Salinity, in addition, assumed constant for Tidal flood)
2 Duration	At various Depths Velocity, Silts, Discharge assumed constant. (Storm, Salinity, in addition, assumed constant for Tidal flood)
3 Velocity	Assumed constant
4 Discharge	Assumed constant
5 Silts	Assumed constant
6 Salinity	Assumed constant
7 Storm	Assumed constant
8 Warning	Assumed constant Implicitly no Warning assumed, as none given (major river food); Warning given in other floods; 'informal' warning implicit in all areas.
9 Flood-to-Peak Interval	Not taken into account
10 Seasonality	Not taken into account
<u>B Property characteristics</u>	
1 Average remaining value	Taken into account
2 Property type	Taken into account
3 Property space	Taken into account
4 Income class	Taken into account
5 Social class	Implicit
6 Perceptions	Taken into account
7 Adjustment	Taken into account
8 Property age & quality	Implicit

APPENDIX A6: APPENDIX TABLES:
OFFICE & ROADS SECTOR (CHAPTER 6)

OFFICE AND PUBLIC BUILDINGS:

Table A6.1: Results of flood loss models : structural damage to office and public buildings - Tangail

Damage component	Model form	Office group	Coefficient of main variables				Coefficient of dummy variables				R^2	Adj R^2	F
			INTERCEPT	DEPTH	DURATION	AREA	O1	O2	O3	O4			
STRUCTURE -Absolute damage -assumed no damage-reducing activity	Log-log	All office group /Main study area	1.9194	.4062	-.0667	1.3436	.1449	2.8428	-.2531	.7163	.80	.78	p<.00
STRUCTURE -Per sq m damage -assumed no damage-reducing activity	log-log	All office group /Main case study area	3.5471	.3860	-.0636	-	.2003	3.0574	.0240	1.0039	.62	.58	p<.00

Table A6.2: Results of flood loss models : equipment damage to office and public buildings - Tangail

Damage component	Model form	Office group	Coefficient of main variables				Coefficient of dummy variables				R^2	Adj R^2	F
			INTERCEPT	DEPTH	DURATION	AREA	O1	O2	O3	O4			
EQUIPMENT FURNITURE -Absolute damage -adjusted for damage-reducing activity	Log-log	All office group /Main study area	6.4315	.3759	.0289	.3303	1.3848	2.3313	4.2039	2.0261	.47	.41	p<.00
EQUIPMENT FURNITURE -Per sq m damage -adjusted for damage-reducing activity	log-log	All office group /Main case study area	3.2538	.3524	-.0025	-	1.4365	1.9082	3.6648	1.9150	.28	.22	p<.00

ROADS SECTOR:

Table A6.3: Mode of transport of inputs and outputs in sample commercial units

Mode of transport/Areas	Industry				Business			
	% of respondents in				% of respondents in			
	Area1	Area2	Area3	ALL	Area1	Area2	Area3	ALL
Mode of transport of inputs								
: Through roads	95	97	97	96	100	100	93	98
: Through water-ways	5	3	3	4	-	-	7	2
Mode of transport of outputs								
: Through roads	97	97	97	97	100	100	97	99
: Through water-ways	3	3	3	3	-	-	3	1
Total no of respondents	58	32	31	121	42	31	30	103

Table A6.4: Reported advantages and disadvantages of roads and water-ways in transporting commercial items

	Industry				Business			
Advantages/disadvantages of water-ways	% of respondents in				% of respondents in			
	Area1	Area2	Area3	ALL	Area1	Area2	Area3	ALL
In terms of money								
: More expensive	73.7	-	7.1	44.1	40.0	54.5	13.0	28.0
: Cheaper	21.1	100.0	78.6	47.1	60.0	9.1	82.6	59.0
: Same	5.2	-	14.3	8.8	-	36.4	44.0	12.8
In terms of time								
: Disadvantageous	89.5	-	100.0	91.2	80.0	72.7	95.7	87.2
: Advantageous	-	-	-	-	-	-	4.3	2.6
: Same	10.5	100.0	-	8.8	20.0	27.3	-	10.2

Advantages/disadvantages of water-ways	% Cost of water transport over road transport				% Cost of water transport over road transport			
	Area1	Area2	Area3	ALL	Area1	Area2	Area3	ALL
In terms of money	26..8	50	119	32	81	21	138	86
In terms of time	173.9	0	224	189	170	138	200	179
X^2 (with activity type) significance level	*	*	*	*	*	*	*	.01

Note :

Cost of road transport assumed = 100.

* X^2 is not estimated due to small cell frequency

Table A6.5 : Roads network by construction type and authority of maintenance: Tangail town

Maintaining authority	Length of roads (Km) *			
	Pucca	Herring-bone	*Kutcha*	Total
Roads & Highways (R&H)	15	-	-	15
Public Works Department (PWD)	3	-	-	3
Pourasava (Municipality)	30	2	45	77
District Council	5	-	-	5
Private	8	2	NA	10
Total	61	4	45	110

Note:
: * Length of roads includes 29 culverts/bridges;
: Pucca = Bituminous roads or made of concrete cement (CC) or rod-concrete-cement (RCC);
: Herring bone(HB): Brick soling;
: *Kutcha* - made of mud.
: Private roads include internal roads, applicable especially for public buildings.

Table A6.6 : Length of town roads and their estimated level of traffic loads

Construction type	Traffic load category			
	A	B	C	Total
Pucca	38	15	8	61
Herring-bone(HB)	-	4	-	4
Kutcha	-	-	45	45
Total	38	19	53	110

Source : Field survey; R&H office; PWD office;Municipality office.

Level of traffic loads:

: A=Highest traffic load
: B=Moderate traffic load
: C=Lowest load

APPENDIX A7: APPENDIX TABLES AND FIGURES: LAND USE AND LAND LEVEL SURVEY (CHAPTER 7)

Table A7.1: Residential households and buildings per household by wards

	No. of units (Household)					No. of building per households				
	House type					House type				
Wards	1	2	3	4	Total	1	2	3	4	Total
Ward 1 (Central)	1189	1133	736	848	3906 (16.6)	1.1	1.6	1.7	1.8	1.5
Ward 2 (Betka)	2825	1838	970	981	6614 (28.1)	1.0	1.6	1.7	1.8	1.5
Ward 3 (Zila Sadar)	831	812	1055	2054	4752 (20.2)	1.0	1.3	1.6	1.6	1.5
Ward 4 (Dighalia)	475	763	615	1769	3622 (15.3)	1.1	1.4	1.7	1.8	1.6
Ward 5 (Santush)	163	434	730	1170	2497 (10.6)	1.1	1.5	1.7	1.7	1.6
Ward 6 (Kazipur)	194	236	347	1390	2167 (9.2)	1.0	1.5	1.6	1.8	1.6
ALL	5677	5216	4453	8212	23558	1.1	1.5	1.7	1.7	1.5
%	(24.1)	(22.1)	(18.9)	(34.9)	(100.0)					

Note:
The figures in parentheses denote percentages

Table A7.2: Average Reduced Level (RL) of properties (at floor height) by major sectors by wards

	Residential					Business	Industry	Office
	House Type				All House types			
Ward	1	2	3	4				
Ward 1	11.3	11.3	11.2	11.2	11.3	11.5	11.9	12.0
Ward 2	11.9	11.9	11.7	11.5	11.8	12.1	12.2	13.1
Ward 3	11.5	11.4	11.6	11.6	11.6	12.7	12.9	12.1
Ward 4	11.6	11.4	11.1	11.1	11.2	12.9	12.4	11.6
Ward 5	11.3	11.7	11.6	11.7	11.6	12.1	11.6	12.0
Ward 6	11.7	11.6	11.5	11.5	11.6	11.9	12.0	12.4
ALL	11.7	11.6	11.5	11.5	11.6	11.9	12.0	12.4
Floor height (cm)	36	28	19	19	27	19	22	36

Note :

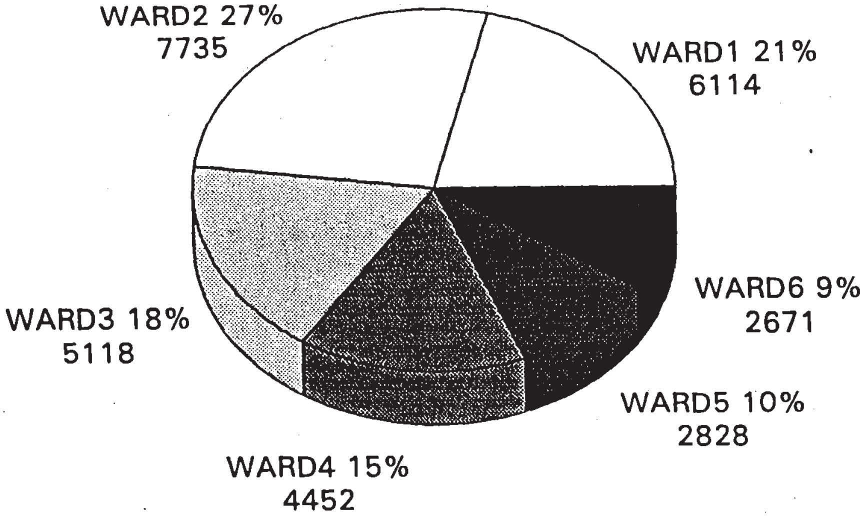
RL = Reduced Level in metres + PWD Bench Mark.

Table A7.3: Land-use survey : Estimated Reduced level and slope factors by roads

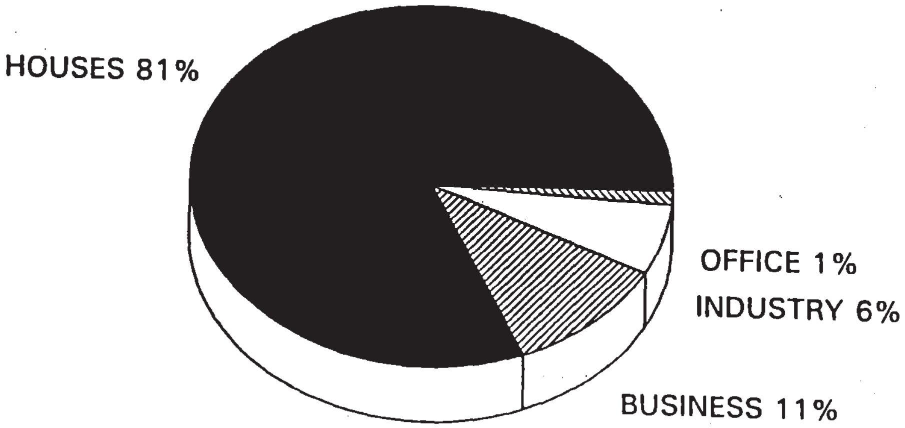
ROAD	WARD	ROAD CODE	AVERAGE DEPTH (M)	MEAN REDUCED LEVEL (M+ PWD)	SLOPE FACTOR (M)
MAIN ROAD-1	W1	1	.92	11.19	1.33
MASJID ROAD	W1	2	1.07	10.88	1.49
BSCIC RD	W1	3	1.17	11.21	1.06
THANAPARA RD(PRINCE)	W1	4	1.07	10.97	1.40
TANGAAIL G SCH RD	W1	5	1.17	10.76	1.51
MALANCHA RD	W1	6	1.45	10.90	1.09
BAJITPUR RD	W1	7	1.32	10.75	1.37
F BRIGADE(P ADALTPR)	W1	8	1.27	11.11	1.06
KALIBARI RD	W1	9	1.07	11.09	1.28
OLD ADALATPARA RD	W1	10	.99	11.29	1.16
DELDUAR CENTRAL RD	W1	11	1.07	11.01	1.36
VICTORIA RD	W2	12	.61	12.01	.82
ZILA SADAR RD	W2	13	1.07	11.57	.80
TANGAIL MYMENS RD	W2	14	.53	11.87	1.03
REGISTRYPARA RD	W2	15	.99	11.36	1.09
CHOTOKALIBARI(AKTAK)	W2	16	1.07	11.90	.48
MES ROAD	W2	17	1.22	11.45	.77
STRAND ROAD-1	W2	18	1.12	12.17	.15
TANGAIL DHAKA RD	W2	19	.61	11.93	.90
ASHIKPUR RD	W2	20	1.32	10.90	1.22
BAILLA ENAYETPUR RD	W3	21	1.02	12.37	.05
TANGAIL MYMENS RD	W3	22	.53	11.86	1.04
GHARINDA RD(SURUJ R)	W3	23	.99	11.39	1.06
DEWLA ROAD	W3	24	1.12	11.95	.37
KAGMARA RD	W3	25	.97	11.42	1.05
DHARAI BARI RD	W3	26	.92	12.07	.46
AMGHAT RD	W4	27	1.25	11.16	1.03
THANAGHAT RD	W4	28	1.17	11.06	1.21
FERRYGHAT RD	W4	29	1.17	11.23	1.04
OMARPUR RD	W4	30	1.07	11.13	1.24
STRAND RD-2	W4	31	1.14	11.13	1.17
KANDAPARA RD	W4	32	1.22	11.10	1.12
SHARUTIA RD	W4	33	1.22	10.35	1.87
SAKRAIL RD	W4	34	1.12	10.61	1.71
KAGMARI DIGHALIA RD	W4	35	1.07	11.59	.79
MAIN ROAD-2	W4	36	.92	11.18	1.35
KAGMARI COLLEGE RD	W5	37	1.14	11.67	.63
SANATUSH RD	W5	38	1.30	11.11	1.03
GHOSHPARA RD	W5	39	1.30	11.07	1.07
PALPARA RD	W5	40	1.42	10.54	1.47
ELASIN RD	W5	41	.76	11.85	.83
ALOWA RD	W5	42	1.37	11.19	.87
KAZIIPUR RD	W6	43	1.20	11.37	.87
KAGMARI RD	W6	44	1.17	11.30	.97
AIRPORT RD	W6	45	1.09	11.83	.52
BHALUKKANDI RD	W6	46	.31	12.59	.55
DELDUAR-KAZIPUR RD	W6	47	1.07	11.01	1.36
Mean			0.88	11.35	1.02
St deviation			.23	0.49	.38
Range			.92	2.24	1.82

Note: The gauging station, Jugini, is 13 Kilometres off from central town.

FIGURE A7.1 : PROPERTIES : TANGAIL TOWN
(BY WARDS)

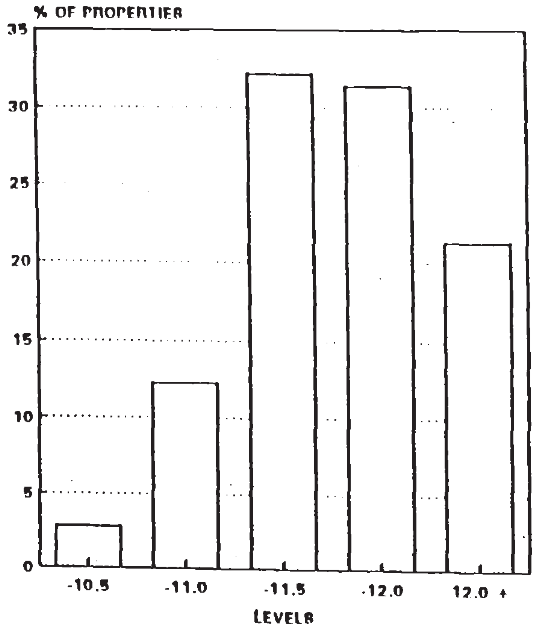


PERCENTAGE OF PROPERTIES : TANGAIL TOWN



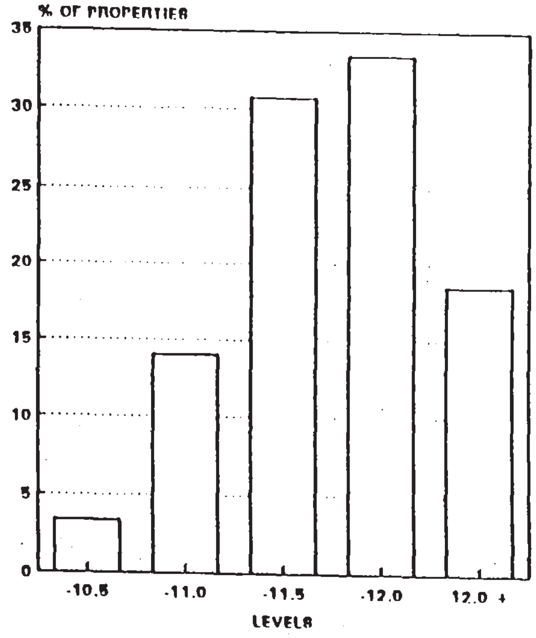
GROUND FLOOR PROPERTIES

FIG A7.2: PROPERTIES AT RANGE OF RLs
TANGAIL TOWN



LEVELS AT FLOOR HEIGHTS (METRES + PWD)

FIG A7.3: HOUSES AT RANGE OF RLs
TANGAIL TOWN



LEVELS AT FLOOR HEIGHTS (METRES + PWD)

FIG A7.4: INDUSTRIES AT RANGE OF RLs
TANGAIL TOWN

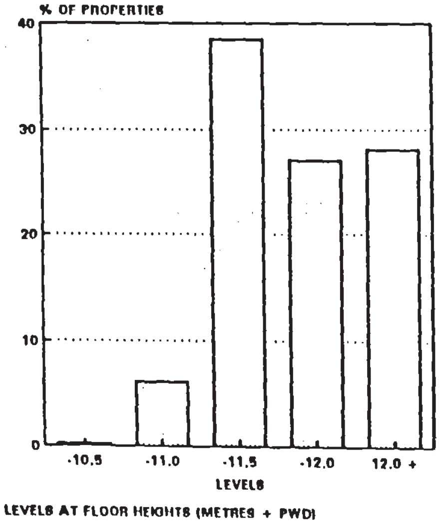


FIG A7.5: OFFICES AT RANGE OF RLs
TANGAIL TOWN

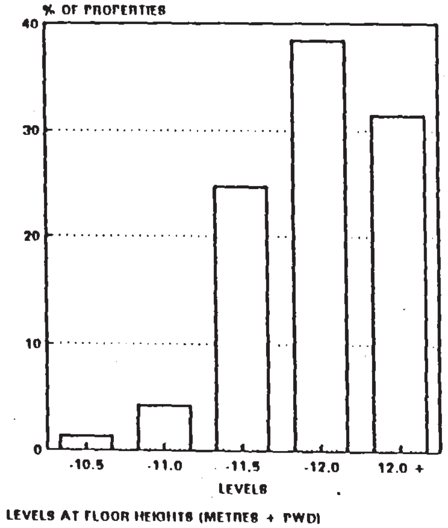


FIG A7.6: BUSINESS SHOPS AT RANGE OF RL
TANGAIL TOWN

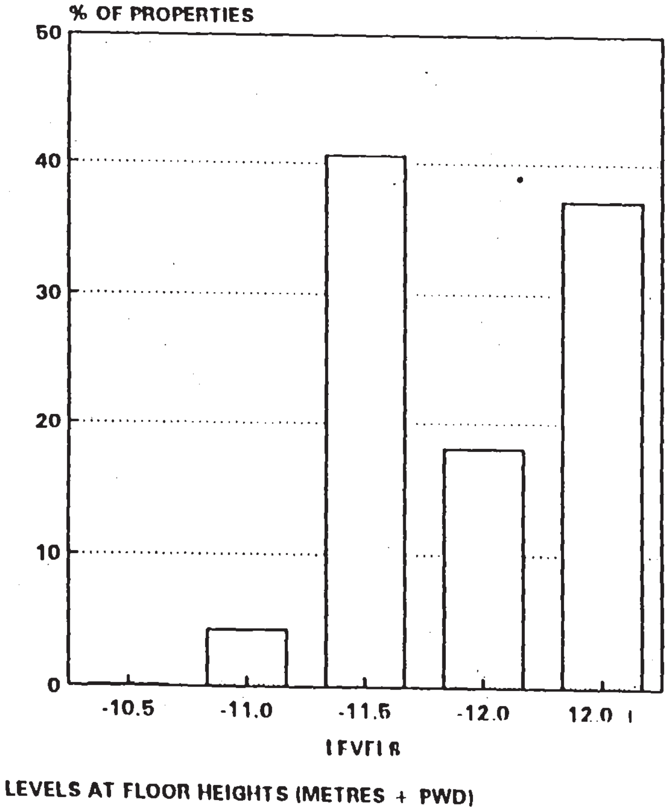
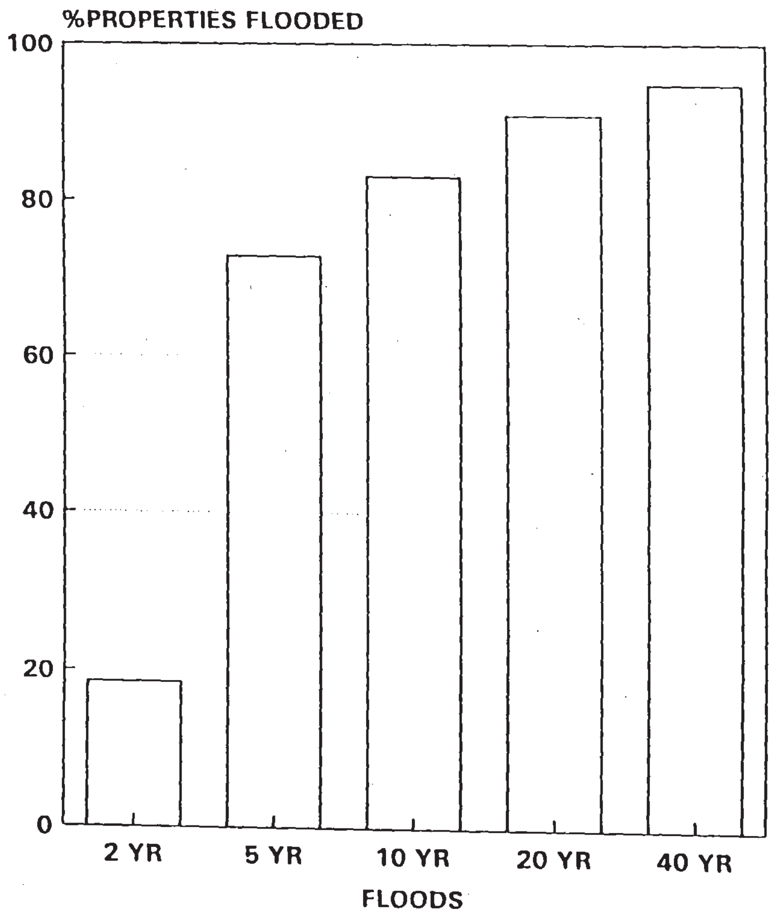


FIG A7.7: %OF PROPERTIES AT RISK BY FLOOD
TANGAIL TOWN



FLOODED AT FLOOR LEVELS

FIG A7.8: % OF TOTAL URBAN LOSS
VARIOUS URBAN SECTORS

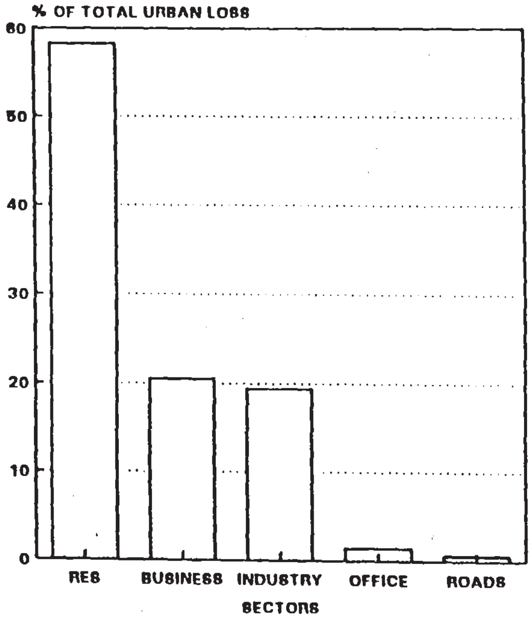
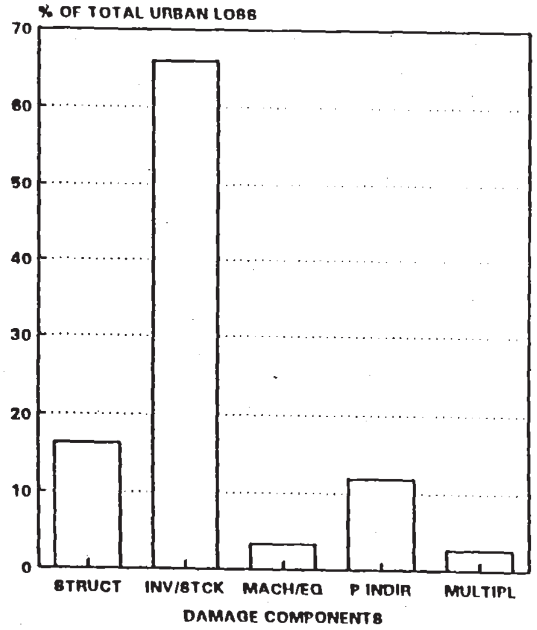


FIG A7.9: % OF TOTAL URBAN LOSS
VARIOUS LOSS COMPONENTS



REF: TABLES 7.8 & 7.9

APPENDIX A8: APPENDIX TABLES: MACRO-LEVEL ANALYSIS (CHAPTER 8)

Table A8.1: Crop damage by type of rice crops by regions during 1962-1991 period

(Damage value in 000 M tons)

Regions	No of districts	Aus loss due to		Total prod.	Aman loss due to		Total prod.	Boro loss due to		Total prod.
		Flood	Cyclone		Flood	Cyclone		Flood	Cyclone	
North West	5	836	-	24012	2668	27	72682	91	33	16390
% loss		3.5	-	-	3.7	0	-	0.6	0.2	-
CV for Districts		.49	-	.45	.41	1.1	.41	.87	.83	.37
Central	4	851	9.7	19221	2429	63	42226	284	184	28165
% loss		4.4	0	-	5.7	0.1	-	1.0	0.7	-
CV for Districts		.67	.75	.80	.47	.55	.78	.82	1.37	.70
South West	6	738	42	23904	1966	846	60000	56	27	10366
% loss		3.1	0.2	-	3.2	1.4	-	0.5	0.3	-
CV for Districts		.68	1.6	.50	.83	1.1	.46	.84	1.52	.60
Eastern	5	1686	97	21727	2376	703	57523	383	460	35182
% loss		7.8	0.4	-	4.1	1.2	-	1.1	1.3	-
CV for Districts		.68	.76	.41	1.21	.65	.49	.67	1.15	.38
Bangladesh	20	4111	152	88864	9439	1639	232431	814	704	90103
% loss		4.6	0.2	-	4.1	0.7	-	0.9	0.8	-
CV for Districts		.81	1.65	.56	.80	1.39	.54	1.19	1.99	.80

Natural hazards excludes droughts, the data of which are not available. Total production denotes the potential production, which is the sum of actual production and the amount lost due to flood. Figures in parenthesis represent loss percentages to potential production; CV - Coefficient of variation for districts.

Source: Compiled from various yearly issues of Agricultural Statistics and Agricultural Production Levels in Bangladesh, BBS.

Table A8.2: Per cent deviations from semi-log trend for agricultural crop production

	RICE CROPS				OTHER CROPS	
	WET SEASON			DRY SEASON		
YEAR	AUS	AMAN	TOTAL	BORO	JUTE	SUGARCANE
1962/63	-21	-1	-7	-31	5	-24
1963/64	-5	18	12	-32	-2	-15
1964/65	-11	16	9	-30	-10	-1
1965/66	4	8	7	-30	14	19
1966/67	-4	-7	-6	-12	9	27
1967/68	10	6	7	8	15	18
1968/69	-4	5	3	45	-1	13
1969/70	6	5	6	58	25	15
1970/71	3	-12	-7	68	17	17
1971/72	-16	-16	-16	24	-26	-13
1972/73	-18	-18	-18	36	15	-19
1973/74	1	-3	-2	35	7	-4
1974/75	3	-14	-10	26	-38	0
1975/76	17	-1	4	19	-29	-11
1976/77	9	-4	0	-21	-13	-4
1977/78	12	2	5	1	-2	0
1978/79	19	1	6	-21	18	1
1979/80	2	-2	-1	-8	10	-6
1980/81	18	24	22	-9	-8	-4
1981/82	17	-7	-1	1	-13	3
1982/83	10	-3	0	5	-8	6
1983/84	16	1	4	-9	-1	2
1984/85	0	-1	-1	-1	-3	-2
1985/86	3	6	4	-14	66	-6
1986/87	13	1	3	-13	30	-3
1987/88	8	-7	-4	-6	-9	1
1988/89	3	-18	-13	7	-13	-6
1989/90	-10	9	3	5	-9	3
1990/91	-16	7	1	0	5	6
1991/92	-21	7	0	-1	5	3
1992/93	-25	10	1	-11	-1	3

Table A8.3 : Estimated semi-log trend equations for selected CMI small and medium-sized industries

Industrial activity	Inter cept	Trend rate of Growth	SE	R^2	F-Signi ficance	D-W Stati stics	N
GROSS OUTPUT							
Rice Milling	1.14	.24	.0305	.88	.00	2.04	10
Handloom	1.86	.11	.0273	.67	.00	1.60	10
Saw Milling	2.12	.16	.0446	.62	.00	1.41	10
Furniture	3.03	.07	.0285	.34	.04	1.05	13
Glass	2.83	.08	.0205	.60	.00	.98	13
Motor Vehicles	4.62	.12	.0295	.63	.00	1.17	12
All	2.19	.11	.0173	.83	.00	1.45	10
GROSS VALUE ADDED							
Rice Milling	.97	.09	.0280	.58	.01	2.19	10
Handloom	1.02	.06	.0235	.46	.03	1.85	10
Saw Milling	.72	.19	.0529	.61	.00	1.26	10
Furniture	2.27	.05	.0283	.23	.10	1.35	13
Glass	2.16	.07	.0224	.47	.01	1.18	13
Motor Vehicles	3.50	.09	.0402	.35	.04	2.32	12
All	1.57	.04	.0190	.38	.06	1.79	10

Note:
Semi-logarithmic trend equation is of the form

Log (Gross output/Value Added) = A + B (Year)

Table A8.4 : Estimated Cobb-Douglas function for selected CMI small and medium-sized industries

Industrial activity	Inter-cept	$\alpha + \beta$	R^2	F-Signi-ficance	D-W Statistics	No of case (N)
	GROSS OUTPUT					
Rice Milling	-5.72	1.31	.91	.00	1.83	10
Handloom	-.64	1.22	.90	.00	1.51	10
Saw Milling	2.56	.93	.88	.00	1.74	10
Furniture	1.34	1.47	.45	.00	1.53	13
Glass	4.76	.71	.41	.00	.89	13
Motor Vehicles	1.83	1.46	.61	.01	1.00	12
All	.57	1.15	.88	.00	.86	10
	GROSS VALUE ADDED					
Rice Milling	-1.66	1.01	.90	.00	1.54	10
Handloom	-.14	1.07	.90	.00	1.70	10
Saw Milling	1.56	.84	.88	.00	2.10	10
Furniture	1.14	1.30	.77	.00	1.51	13
Glass	5.40	.51	.81	.00	1.32	13
Motor Vehicles	.90	1.49	.60	.01	1.93	12
All	2.88	.80	.89	.00	.90	10

Note : Cobb-Douglas function

Log(output/value added) = a + α log(fix asst) + β log(employment)

Table A8.5: Deviation from trend on productivity (gross output/employment) for selected CMI small and medium-sized industries

Year	Deviation from Trend (000 TK)			% Deviation from Trend		
	Rice mill	Hand loom	Saw mill	Rice mill	Hand loom	Saw mill
1979/80	-2.75	5.39	3.26	-34	54	21
1980/81	1.65	-61.00	1.42	16	-5	8
1981/82	-1.83	-3.05	-0.44	-14	-25	-2
1982/83	6.19	-1.50	-3.94	37	-11	-15
1983/84	6.60	-1.32	-10.36	31	-9	-34
1984/85	-3.25	-4.96	-14.00	-12	-29	-40
1985/86	15.45	5.29	37.38	46	27	90
1986/87	-3.15	1.50	29.70	-7	7	61
1987/88	-7.46	4.12	7.61	-14	17	13
1988/89	-12.39	-0.55	-21.64	-18	-2	-32
Year	Furniture	Glass	Motor repair	Furniture	Glass	Motor repair
1979/80	-3.90	15.38	-33.03	-14	65	-20
1980/81	-1.38	10.60	-38.76	-5	41	-21
1981/82	-1.09	11.34	-46.19	-4	41	-22
1982/83	10.48	4.22	-122.17	32	14	-51
1983/84	11.65	-1.14	38.36	33	-3	14
1984/85	4.87	0.43	107.63	13	1	36
1985/86	17.80	-7.70	146.78	44	-20	43
1986/87	19.53	-1.18	96.74	45	-3	25
1987/88	6.48	-8.41	32.91	14	-18	8
1988/89	-31.79	0.35	-121.46	-64	1	-25

Note :
Trend estimated from semi-logarithmic equation on productivity (annual output/employment)

Table A8.6 : Deviation from trend on productivity (value added/employment) for selected CMI small and medium-sized industries

Year	Absolute Deviation from Trend (000 TK)			% Deviation from Trend		
	Rice Mill	Hand loom	Saw Mill	Rice Mill	Hand loom	Saw Mill
1979/80	-0.42	1.92	0.87	-14	54	20
1980/81	0.04	-0.71	0.02	1	-19	0.42
1981/82	-0.77	-0.94	-0.27	-17	-23	-4
1982/83	1.32	-0.21	-1.83	26	-5	-24
1983/84	0.98	0.26	-3.75	17	6	-41
1984/85	-1.46	-0.71	-2.04	-24	-15	-18
1985/86	2.67	0.66	18.21	40	13	136
1986/87	0.96	-0.42	9.63	13	-8	59
1987/88	1.29	0.75	4.12	16	13	21
1988/89	-2.99	0.24	-11.38	-33	4	-48
Year	Furniture	Glass	Motor repair	Furniture	Glass	Motor repair
1979/80	0.29	9.76	-14.61	2	85	-31
1980/81	-.44	5.20	2.23	-4	42	4
1981/82	.49	3.79	-4.99	4	29	-9
1982/83	2.42	2.13	-27.08	18	15	-43
1983/84	-1.14	-2.51	134.61	-8	-17	194
1984/85	-1.57	1.49	26.98	-10	9	35
1985/86	8.14	-5.23	-20.83	51	-30	-25
1986/87	13.04	-1.20	60.57	77	-6	66
1987/88	3.56	-1.65	-16.92	20	-8	-17
1988/89	-11.30	1.17	-41.95	-60	5	-38

Note:
Trend estimated from semi-logarithmic equation on productivity (annual value added /employment)

Table A8.7 : Deviation from trend on annual gross output for selected CMI small and medium-sized industries

Values in 000 TK at constant 1976-77 prices

Year	Absolute Deviation from Trend			% Deviation from Trend		
	Rice Milling	Hand loom	Saw Milling	Rice Milling	Hand loom	Saw Milling
1979/80	-6822	-31523	-252	-38	-12	-9
1980/81	4336	12755	214	21	6	9
1981/82	3465	8791	391	18	4	16
1982/83	-3135	11152	802	-7	4	36
1983/84	-3616	-36873	-2704	-42	-10	-43
1984/85	8134	-85143	-2118	16	-22	-34
1985/86	11726	31445	6600	15	4	28
1986/87	6044	123857	7736	10	18	33
1987/88	24529	155407	1665	43	25	7
1988/89	-8306	313931	-36508	-25	-9	-7

Year	Furniture	Glass	Motor repair	Furniture	Glass	Motor repair
1979/80	-4709	-294	-36900	-16	-1	-41
1980/81	-9802	-4001	-17281	-23	-9	-22
1981/82	-7523	4256	-18734	-18	10	-21
1982/83	7028	3731	-56398	17	8	-57
1983/84	14695	2839	12250	33	6	12
1984/85	-23604	13724	54300	-24	26	58
1985/86	24473	4874	86557	41	10	94
1986/87	36412	12493	93937	86	21	86
1987/88	15658	11007	61710	27	20	73
1988/89	-52125	2761	-73446	-46	-4	-28

Note:
Trend estimated from Cobb-Douglas function on output

Table A8.8 : Deviation from trend on annual value added for selected CMI small and medium-sized industries

Values in 000 Tk at constant 1976-77 prices

YEAR	Absolute Deviation from Trend			% Deviation from Trend		
	Rice Milling	Hand-loom	Saw Milling	Rice Milling	Hand-loom	Saw Milling
1979/80	-661	3582	-111	-9	4	-13
1980/81	801	-4169	22	10	-6	3
1981/82	78	2081	124	1	3	18
1982/83	287	7946	223	2	9	38
1983/84	-4310	3587	-1075	-26	3	-51
1984/85	-1956	-12747	-258	-14	-11	-13
1985/86	1743	-12754	3324	11	-6	38
1986/87	969	-7802	1694	7	-4	20
1987/88	3506	14196	508	27	8	6
1988/89	5461	17294	-9656	2	2	-7
	Furni-ture	Glass	Motor repair	Furni-ture	Glass	Motor repair
1979/80	-284	2989	-13356	-2	13	-50
1980/81	-2888	-1998	-3746	-17	-9	-14
1981/82	-1128	4	-5963	-7	.02	-21
1982/83	1617	2145	-12668	10	10	-49
1983/84	-1258	-1418	4919	-7	-7	186
1984/85	-9316	9366	12185	-28	41	48
1985/86	12055	-643	-2174	53	-3	-9
1986/87	19955	4232	33459	114	16	110
1987/88	7669	8001	5070	35	34	24
1988/89	-23507	-2204	-17059	-48	-7	-33

Note:
Trend estimated from Cobb-Douglas function on value added

Table A8.9 : Trend estimates of GDP for various sectors of the economy

Sectors	Inter cept	Trend rate of growth	Standard error of estimates	R^2	F Signif level	D-W statis-tics	No case (N)
Agriculture							
current price	9.34	.118	.0068	.95	.00	1.47	19
constant Price	10.04	.021	.0012	.95	.00	2.55	19
Industry							
current Price	7.26	.138	.0070	.96	.00	.77	19
constant Price	7.82	.054	.0034	.94	.00	1.10	19
Large Industry							
current Price	6.13	.011	.0108	.93	.00	.80	19
Constant Price	6.70	.079	.0078	.86	.00	1.13	19
Small Industry							
current Price	6.97	.113	.0055	.96	.00	1.04	19
constant price	7.53	.028	2.75E-05	.92	.00	1.33	19
All Sectors							
current Price	9.71	.139	.0052	.90	.00	1.30	19
constant price	10.50	.037	7.76E-04	.90	.00	2.67	19

Note : Deviations taken from semi-log trend on gross output.
: Constant price of 1984-85 price.
: Reference period = 1972/73 - 1990/91.

APPENDIX A8:9

Table A8.10: Percentage deviations from trend on for major sectors of the economy

Year	% Deviation from trend (at current price)				
	Small industry	Large industry	All industry	Agricul-ture	National GDP
1972/73	-31	-57	-42	-33	-1.48
1973/74	-6	5	-2	-5	-.30
1974/75	34	3	18	60	1.57
1975/76	8	-2	2	4	.35
1976/77	-3	12	3	-10	-.14
1977/78	-2	13	4	3	-.08
1978/79	-6	24	7	4	-.25
1979/80	4	35	18	.21	.18
1980/81	7	22	13	-2	.25
1981/82	8	10	8	-3	.32
1982/83	10	18	13	4	.39
1983/84	8	23	15	8	.28
1984/85	7	8	7	12	.27
1985/86	5	.72	2	3	.16
1986/87	-3	2	-2	8	-.09
1987/88	-6	-11	-9	.17	-.19
1988/89	-7	-17	-12	-6	-.22
1989/90	-8	-16	-11	-7	-.23
1990/91	-6	-20	-12	-8	-.19

Table A8.11: Trend estimates of semi-log models for prices

Prices for	Intercept	Trend rate of growth	SE	R^2	F Signif. level	D-W Statistics	Cases (N)
Food	4.44	.096	.0053	.95	.00	1.27	20
Rice	4.90	.076	.0050	.93	.00	0.96	20
Manufacturing	4.83	.081	.0067	.89	.00	1.79	20

Note:

Rice price = Taka/Quintal;
Food and manufacturing = Price index (1970=100)
Reference year = 1972-91

APPENDIX B

APPROACH TO SAMPLING TECHNIQUES AND SAMPLE SIZE DETERMINATION

B1 Approach to Sampling Techniques

The analysis of the present research and subsequent data sets generated have limitations in applicability at the national level. The damage data sets are constructed in a case study area of a typically secondary town - a town which predominates small and cottage type of industrial and commercial activities. Naturally, damage data collected are not expected to cover the diverse range of activities that exist across the country. Hence, the present data sets are applicable to secondary towns, rather than to the cities, where large-sized industrial and commercial enterprises are generally located. This discussion of the approach to sampling techniques and sample size determination is related to that adopted in the present analysis, and what ought to be adopted in the case of constructing the national data sets.

A nationally applicable data set needs to be representative of regions, and the type and scale of diverse activities. This demands a multi-stage probability sampling technique to be adopted. The multi-stage sampling procedure involves four sampling designs: stratified sampling, cluster sampling, systematic sampling and simple random sampling. A stratified sampling procedure that ensures adequate inclusion of different regions and groups of activities usually increases the level of accuracy in estimating parameters. At the first stage, the entire geographical area may be stratified into 6 broad regions, called strata, according to ecological characteristics[1]. A further stratification of towns is necessary to cover small and large enterprises, as generally small and cottage type units are concentrated in rural and semi-urban areas while the large and medium-sized units are localised in big towns and cities. A random sample of towns is then selected, which are called primary sampling units (PSU).

Each of the PSUs is further sub-divided into such areas (or 'chunks', as they can be called)

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[1] The stratifications are used primarily to ensure that different groups are adequately represented in the sample; the sampling theory dictates that in order to achieve higher precision the units within strata are as homogeneous as possible and those between strata are as heterogeneous as possible. The Master Plan Organisation (MPO 1992) has divided the country into 6 broad regions according to ecological characteristics.

as blocks/wards from which a random sample of clusters of industries, shops and housing estates are selected for ultimate investigation. Alternatively, the roads by which the properties are located may also be selected. At this stage, the clusters of properties can physically be visited, and a sampling frame listing all the units can be prepared. Finally, depending on the actual situation, a selection of a specific fraction of the properties from within the clusters can be made using a simple random or systematic sampling procedure[2]. A systematic sampling procedure is usually more convenient from the cost and supervision point of view, which involves selecting the first property at random and the remaining units selected according to sampling interval (i.e. N/n). In fact, a systematic sample can be regarded as a simple random sample provided the sampling units are not located in a sequence which may be related to the variable to be measured. The properties of houses or industries or business are not, however, expected to follow any such sequence.

The choice of sampling design including the choice of strata and clusters is important. In any large socio-economic survey, stratification by some category is almost inevitable for some reason or other. Estimates of the parameters of the population are derived from the individual stratum estimates. The variance of the overall estimates is the sum of the individual stratum variances. The variance between strata does not contribute to sampling error so that if strata of relatively homogeneous units can be formed the precision of the overall estimate for a given sample can be considerably improved. In other words, stratifications even with a smaller sample ensure the same level of precision as that of a simple random sample.

B2 Sample Size Determination

The determination of sample size is a crucial factor for any social survey that aims at inferring population characteristics. As in most real situations of socio-economic surveys, the present study is also constrained by limited time and resources. The present research involves estimating damages to properties and thereby generating potential data sets in the study area. The main case study area comprises 6 administrative units (called Wards), which are assumed to approximately correspond 6 different hydrological units. The selection of sample from roads selected in each of the Wards enables coverage of diverse 'depths' and 'durations'.

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[2] If, however, the clusters are small and the resource available is adequate, all of the sampling units in each cluster can be included in the final interview.

The proposition that a sample is required to be a certain proportion of the population size or a definite number is frequently pronounced. However, this seems to be a faulty notion having hardly any basis in sampling theory. The size of the sample is indeed primarily contingent upon the expected level of accuracy. That is, it is dependent on deciding how large a standard error (S.E. i.e. error margin or sampling error) is acceptable, given the resources available. The standard error can be estimated by dividing the standard deviation of the sample by the square root of the sample size (n); that is, S.E. = s $/\sqrt{n}$ or, $(S.E)^2 = s^2/n$. However, if the population is small (or the sample is too large relative to population), the factor (1- n/N), called the finite population correction, has to be included in the equation. In other words,

$$n = \frac{s^2}{(S.E.)^2}\left(1 - \frac{n}{N}\right) \qquad (1)$$

The equation, as a simple and general rule, gives the appropriate size of sample. In practice, however, sample size determination may not be so straightforward. Under the classical theory of probability sampling, there are other factors which need to be considered. First, the inherent variability of the variable under study is to be measured in terms of coefficient of variation V, not the variance, S^2. Second, the required level of confidence, which is the true value of the population parameter lying within a specified margin of error, is to be included. This is measured in terms of E, the standard normal deviate. The required sample size n is then given by

$$n = \frac{E^2 \; V^2}{D^2} \qquad (2)$$

where, D denotes the Standard Error of estimate (Casley and Kumar 1988)

This approach to deriving desired sample size is beset with several problems. First, the assumption for the variables to have normal distribution is not always valid. Many flood loss variables are likely to have rather skewed and non-normal distributions. This can, however, be surmounted through approaches such as semi-log and double-log transformations.

The values of D and E depend on the required (or acceptable) levels of precision and confidence respectively, which are best determined by the researcher depending on situations. For all sample data there exists a non-zero probability that the true population of the parameter being estimated lies outside the limits set be D. The probability that the true value lies within the limits is expressed in terms of E, the standard normal deviate. As an illustration, D=0.1 indicates an acceptable margin of error of 10 per cent of the mean. In case of differences between groups or areas, the minimum difference which can be accepted is twice the margin of error on the individual group means. Thus if group means are estimated within ± 10 per cent, the minimum statistically acceptable difference between them is 20 per cent.

There are potentially large variabilities across a large number of flood variables. For a given precision and confidence level, then, the required sample size is expected to be different for different variables. It is then appropriate to consider the variance of the key variable while determining the sample size for various sectors. Structural damage, for instance, can be the key variable for residential sector while stock damage can be the key variable for the industrial/commercial sector. As there has been no previous study of flood damages, particularly on non-agricultural sectors in Bangladesh, the variance of damage can hardly be obtained. A pilot survey for determining the variability could assist, but this is not feasible in terms of the cost of the survey. However, a value of 0.5 for V may be used, as is often followed in many agricultural and socio-economic variables in developing country situation (FAP-12, 1992).

The equation 2 is applicable only to a simple random sample, a sampling technique that must have a complete sampling frame. In practice, however, the use of cluster sampling at some stage is inevitable following the lack of a complete sampling frame in many a cases. But the problem arises in that cluster samples usually show some positive intra-cluster correlation; that is members of the same cluster tend to be more similar to each other than to members of other clusters. It means that cluster members are not fully independent observations, and therefore, the precision of the estimates obtained is lower than that for the simple random sampling of the same size. The loss of precision (Z) depends on the size of cluster (M) and on the intra-cluster correlation (δ), the relationship being

$$Z = 1 + \delta(M - 1) \qquad (3)$$

(Casley and Lury 1985)

Where,

$$\delta = \frac{\sigma_b^2 - (\frac{\sigma^2}{M})}{(M-1)(\frac{\sigma^2}{M})}$$

The magnitude of δ is not usually known, but for illustration, it is assumed to be 0.20[3]. For a cluster size (M) of 20, for example, the value of Z works out as 4.8; that is, with cluster size of 20 the sample size, for a given precision and confidence level, is about 5 times that of a simple random sample given by Eq 2. This suggests that cluster effect has a serious influence on the sample size. On the other hand, cluster sampling is unavoidable in a survey such as the present one. Table B1 depicts a comparative analysis of the required sample size for different sampling techniques, given V = 0.5 and S.E.(D) = 0.1 under various levels of confidence. The required size of cluster sample is worked out for M = 10 and δ = 0.2. The size of samples is worked from Eq 1, for simple random sample, and from Eq 2, for cluster sample.

Table B1: Sample sizes required under various sampling techniques and levels of confidence

E	Confidence level (2-tailed)	Sample size	
		SRS	Cluster
1.00	68	25	78
1.15	75	33	92
1.28	80	41	115
1.64	90	67	188
1.96	95	96	269

SRS - Simple random sampling

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[3] Casley and Kumar (1988) suggests that the size of δ for agricultural applications is approximately 0.2.

If the inherent variability, that is, the variance of the variables under study are considered, which is likely to be much higher than what has been used in this calculation (eg 0.1), the sizes of the sample required would be many-fold.

The generation of standard damage data sets with national applicability is more demanding in terms of cost and resources. The trade-offs of costs between primary sample unit and final sample units are, however, feasible from the multi-stage sampling technique, the approximate optimum sample size of which is

$$n=\sqrt{\frac{C_1}{C_2}\frac{1-\delta}{\delta}}$$

(Casley and Lury 1982), where n is optimum sample size, C_1, the cost of adding a PSU, C_2, the cost of including an extra final unit, and δ is the intra-class (stratum) correlation. If δ is .10, for instance, then the optimum size will be $3\sqrt{\ }(C_1/C_2)$.

It is evident from the above discussion that the size of a cluster sample has to be much higher than a simple random sample. So, the study is open to criticism in that the sizes of the sample are far from what are required. Apart from the problem of time and resources, the other barrier towards adopting an unrestricted random sampling is the non-availability of an appropriate sampling frame from which to select the sample. Had this frame even been available, the inclusion of various Wards, roads and property types makes it entirely insurmountable to adopt simple random sampling. Given the research objectives and questions there are no other alternatives to a restricted random sampling technique. However, given the limited resources in terms of cost and time, and following that all the Wards are included and the subsequent selection of the roads and properties is done randomly, the sizes of the sample are adequate for valid statistical tests as, 'variance of, hence the precision of, estimates calculated from sample data, is a function of the absolute number of units, not the sampling fraction' (Casley and Lury 1982).

APPENDIX C

DEFINITIONS, PRINCIPLES AND LIMITATIONS OF MEASUREMENTS OF FLOOD VARIABLES

C1 Introduction

Even though the study is concerned with tangible impacts, the quantification of some impacts poses some problems. One basic reason is the absence of market (or its ambiguity) for some of the variables under investigation. For example, many of the household impacts involve goods which are not normally traded in a market. The collection of data thus involves some measurement problems. The broad principles and problems of measurement including data limitations are discussed below.

The collection of damage estimates for a range of flood depths and durations in one or a few locations is rarely possible due to a host of reasons, including the lack of variations of depths and durations. The one alternative is to assess the potential damages for hypothetical scenarios through subjective judgements of the respondents, estimated on the basis of the damages actually occurred. As knowledge is derived from the acquisition of experience and perceptions, the approach appears to be realistic. Nevertheless, the estimation approach is associated with both inadvertent and advertent errors (in both directions). Although the two-way biases are largely expected to cancel each other out, there still might remain some errors because of variations in individuals' judgements and damage characteristics. Although the literacy level of the property owners in urban areas is relatively high, a considerable number of them are illiterate. Even then, they emerge not 'uneducated', as they appear to be quite good at estimations, particularly in calculations of 'proportions'[1].

C2 Recall and Reference Period

The survey was conducted during July-December 1993, investigating three types of floods

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[1] The respondents appear to be quite conversant with percentages, which they easily calculate in their head, in relation to the unit value of currency - Taka. Until recently, one Taka used to be consist of 16 Annas, and accordingly they appear good at arithmetic of proportions. For example, they are in the common practice of equating one anna with 6 per cent, two annas with 12 per cent and so on.

which occurred at three different points in time. The first type refers to a river flood that occurred in August-September 1988 while the second one (flash flood) took place in July 1993 and the third (tidal flood) occurred in April 1991.

Three different situations are encountered in respect of the recall problem in the three case study areas. It was earlier suspected that the survey of the main case study area would suffer from the problem of recall, especially the damage details. In the actual data collection, fortunately, this has not appeared so. The 1988 flood experiences are so dreadful that these appear to be still vivid in the respondents' memories. It turns out hardly a serious problem to make the respondents recapitulate and estimate their 'major' but 'uncommon' expenditures on the damages. The situation has been particularly eased following that the recovery activities by and large are stretched over a long period. In a few cases, however, the powers of recall on the part of the respondents are cross-checked by repeating the interview with the same interviewees, and it proves not significantly different.

As regards the second case study area, on the other hand, the interview carried out immediately after the flood occurrence (flash flood in Bahubal) poses several other problems. A large majority of the damages remain unattended for repairs and restorations; and it is difficult for respondents to estimate the damages suffered. Thus the estimates provided by the victims in many cases have not been based on actual repairs. The victims are too stressed to respond unless they are given some false hopes of grants. As a matter of fact, the victims gathered not to be interviewed, but for only their names to be enlisted in the hope of some reliefs. It is indeed difficult to tackle such a situation from a humanitarian and survey consideration. However, close co-operation with the local authority in the end proves helpful in effectively undertaking the survey. In the third study area, the tidal flooding is catastrophic and the signs of destruction are still existent. The recall problem has not posed a serious problem. As most of the damages are recovered, it is not difficult to obtain estimates of the damages based on actual recovery activities. The reference periods, which are the intervals of time to which the questions relates, are short, and these are equal to the duration of floods for most of the questions (except for the those for repair expenditures). Thus the study has generally no problem with data collection on the reference periods.

C3 Target Respondents and Scale of Measurements

The respondents include householders and entrepreneurs. A household includes members having food in one cooking arrangement. The head of household, rather than other members, are preferred for the interview. In the case of industrial or business units, those who run the enterprises are preferred for the interview. In the residential sector, the four house types in the sample represent broadly four socio-economic groups, including the lowest income class.

The investigation in the commercial sector includes industrial and business units, as much as possible across various sizes and types in order to represent variations within groups. Besides the merit of generalising, this has the added advantage of examining the vulnerability of the smaller units in particular. As regards the size of the industries, in line with the definition of Census Manufacturing Industries (CMI), small units are defined as those employing less than 20 workers, operating with or without power, regardless of the amount of capital employed. Medium-sized industries are defined as those employing 20 or more workers but less than 50 workers, and the large-sized units as those employing 50 workers and above.

The study generally adopts the definition of 'Region' envisaged by the Master Plan Organisation (MPO 1990) and Flood Action Plan (FAP 1992). The country is divided into 6 ecological regions: North West (NW), North Centre (NC), South West (SW), South Centre (SC), South East (SE) and North East (NE). However, in the context of 'linkages', the study considers 'Region' as the rest of the District/'greater' District within the Regions.

As in a quantitative investigation leading to statistical interpretations, the study seeks information measured largely on either an interval or a ratio scale. Nonetheless, the qualitative information is sought on an ordinal scale in the form of ranks or scales.
Although depths of flooding and floor heights are more often made through eye estimation, cross-checks are carried out to ensure the precision of the estimates, as the precision on these two variables is crucially important in the context of fruitful regression analysis.

C4 Property Specifications and Flood Variables

The study is concerned with damages to properties of ground floors only. Initially, separate schedules for more than one buildings were intended to be administered. Nevertheless, constraints of resources and time did not allow this to be pursued. Only the principal buildings are included in the interview. In urban areas it is only few owners that have more than one main building or floor. The damages to other buildings, if any, other than the main buildings are amalgamated under 'other damages'. This category includes kitchens, outside toilets, livestock sheds and other buildings. While installations generally are considered to include electricity, gas and water establishments, under this item the present research includes safety tanks and tube-wells.

As also generally in Bangladesh, houses in the three case study areas are located in clusters. This is more so in case of low-cost houses particularly in secondary towns. In other words, open spaces are often jointly owned. Some open spaces are even owned by government or public bodies, which are encroached by individuals. Hence it is difficult to exactly ascertain the amount of open space owned by individuals. Hence there is possibility of ambiguity in the assessment of open spaces under individual ownerships.

Frequency of flooding is related to the present property and the present occupant. The evaluation of frequency of flooding since the occupation of the residents at the present site is beset with problems in that the young owners will have fewer experiences than those living for a longer period. The problem is partially surmounted by standardising the frequency with living years. Another type of error is likely to crop up when the young owners are unaware or unable to recall, and/or when they can only recapitulate the events that were most devastating and vivid in memories. In the case of the flash flood area (Bahubal), flash floods occurred twice or three times shortly before the flood under investigation. But as the damage estimates need to be attributable exclusively to a single flood, such samples are purposively excluded in the survey. Thus in this area frequency of flooding is not adequately captured.

The determination of threshold is somewhat ambiguous in that a property actually starts damaging, albeit negligibly, at an infinitely small magnitude of either depth or duration. The present analysis defines threshold as that limit at which the property starts damaging considerably (according to respondents' judgment).

External conditions of properties are assessed based on visual judgments. However, general guidelines for the assessments are briefly as follows:.

Poor condition - Little sign of recent maintenance; wall paints decayed and crumbling brickwork (in case of brick walls); rusty walls (in case of CI sheet); broken walls (in case of thatched); grounds untidy.

Fair condition - Static maintenance condition, natural decay but not too severe; wall paint ageing and dirty but still adequate protection; roof and gutters not leaking although patches of rust may be evident; grounds more or less tidy.

Good condition - Natural decay not evident by good maintenance; new painting on walls; parts of walls likely to have been renewed and possible new additions; grounds well kept.

In order to assess the proportion of the total value of contents/stock exposed to floods, the total value of contents (item by item, as per check list) before the flood event is first estimated. On the basis of existing positions of goods, the approximate proportions of the risky items are then reached. The method of arriving at estimates of potential damages is described in Section 2.6.2. Damages avoided through protection or removal are estimated net of expenses, if any.

Evaluating damages to trees and the kitchen gardening is beset with problems in that it is difficult to ascribe present values to production that are likely to be achieved in future. The future benefits and costs are not taken into account in the present analysis, but only the present worth is incorporated. Damages are, however, estimated net of scrap values, if any. The same approach is adopted in cases of poultry, dairy or fisheries.

C5 Fixed Investment and Working Capital

In industries and business sectors, data collected on fixed investments include fixed capital such as building, machinery, equipment and fixtures (other than land) employed in ground floors. The value of such assets represent resale value at current prices. Uses are made of published and unpublished reports on profit-loss accounts, where available. For business units particularly, care is taken so that ‘possession values’ (premium) are not included in the fixed investments.

In the present analysis working capital represents only stock in the form of inputs and outputs, excluding credits and cash at hand and/or banked. The working capital is expected to vary significantly over the year - which is in general dependent on agricultural seasons. Thus the capital is assessed by considering production fluctuations and the corresponding flow of stocks over peak and non-peak months. Similarly, the estimates of average employment and output/turnover have incorporated seasonal fluctuations.

C6 Warnings and Hypothetical Floods

The damages estimates in hypothetical floods are based on the assumption of no formal warning given. In the main case study area no formal warning was given and depth-damage data sets are constructed only for this area (i.e. for river flood). The damage-reducing activities based on the occupant's perceptions are, however, postulated. The suitability of four hypothetical flood scenarios is tested during the questionnaire pre-testing and reconnaissance survey, so that the respondents find minimum difficulties in making the estimates. The prime determining factors, e.g. depths and durations, are doubled from one scenario to another with a view to achieving easy responses. Table C.1 shows the scenarios in the three different floods.

C7 Interaction and Main Effects

It poses a problem when one intends to compare the damageability in three different types of flood, caused by only inundation. The problem is severe in the case of the tidal surge, which comprises three additional damage factors (high Velocity, Storm and Salt apart from Inundation). In such case there can have as many as six (${}^4C_2$) two-way interaction effects aside from the four main effects. Apart from that, there can be another three (${}^3C_1$) three-way interaction effects.

The task of separating out the interaction and the main effects is not readily surmountable, which is indeed beyond the scope of the present research. However, assuming that the two and higher order interaction effects are negligible, the major task, that is, the evaluating and segregating of the main effects is undertaken, using the knowledge and experience of the flood plain managers. Thus, the respondents (of the flash and tidal flood area) were asked to segregate (in %) their total damages caused to them, for each of the three major damage components (e.g. structure, inventory and others) on account separately of Inundation, Velocity, Storm and Salinity. The responses are collected considering the respective total component damage to be 100, and obviously, ignoring the interaction effects. The survey experience shows that the respondents can segregate the effects of the main factors without much difficulty. This is less difficult in the case of flash flood, having only two damage factors (namely Inundation and Velocity). The variance of these estimates is also found to be not very high. The 2-way interaction effects are evaluated through carrying out an Analysis of Variance (ANOVA) in relevant chapters.

C8 Recovery and Recovery Curve

The slope of the average production curve (during the partial recovery period) is important for a precise damage estimate. However, due to long recall periods especially in the case of the 1988 river and 1991 tidal flood, it was not useful asking for estimates over every point in time of the recovery period. Thus, a curve with a slope of 45^0 passing through the origin is assumed, representing a uniform proportion of recovery activities over the period. This is associated with some amount of errors; however, averaged over all groups of enterprises, the errors are expected to be minimum.

Additional costs in the process of recovery of production loss are the variable costs, namely overtime or extra incentives to workers, extra fuel and extra hire of equipment. The days of probable closures, complete and partial, at various hypothetical flood scenarios are estimated without much difficulty, but it appears too demanding on the part of the respondents to provide estimates of the potential extra costs during the recovery of hypothetical floods. In such cases, additional costs during recoveries at hypothetical floods are estimated on the basis of those in actual events.

C9 Household Occupation and Indirect Impacts on Households

Main occupation refers to that which provides the major income regardless of the amount of time spent on it. The gross annual income for households is estimated from average monthly income earned by all members of the households from all sources.

At household levels, the impact on employment in terms of person days is first estimated during the flood and its aftermath. Some households experienced both positive and negative impacts on working days during these two periods, which are later combined to provide the net impact. Against the losses/gains in person days, net impacts on the total income in the households are estimated. As the study concerns non-agricultural impacts the damages to crops are not included in the estimate of the income lost. The service-holders have in general incurred losses in working days without any losses in income.

An idea of the trend in the immediate impact on employment, income, prices and wages in the case study town, as a whole, is gathered based on the householder's individual experience and knowledge. The trends are estimated as percentage changes (increased, declined, or remaining the same during the period of 6 months following the flood), due specifically to flood effects, compared to the pre-flood level (during the period 6 months before). The householders have rarely found any difficulties in estimating the percentages. The estimates cast an idea about the overall situation in the post-flood period. For the flash flood case in Bahubal, however, the estimates have the likelihood of being overestimated due to stress, emotions and the hope for grants.

In order to explore whether demographic and social linkages, such as community ties and kinships play any role in the reduction of flood losses, some information mostly in the form of qualitative pre-coded questions is pursued. The variables are measured mostly on an ordinal scale. The health and property risks from flooding, mental stress and depression are also assessed on the ordinal scale of measurement. The effects and risks are scaled starting from 0 (no effects) to 5 (maximum effects).

The trend of changes in average medical expenses six months after the flood, compared to that six months before, is first obtained on an ordinal scale. Then the normal medical expenses, averaged over six months before the flood, and the percentage difference in the aftermath is obtained, from which the impact on average medical expenses is estimated. This information could not be pursued in the case of flash flood area.

C10 Use of Deflators

The three floods under study occurred at three different places at three points in time. Thus in order to be able to compare damage estimates caused by the three floods, the damages must be converted to constant prices. The three floods took place in the year 1988 (August-September), 1993 (July) and 1991 (April) respectively. The survey was conducted during June-December 1993 so that the financial year, July 92 -June 93 is approximately taken as the reference year (Table C2).

The range of recovery time, more often a long period, is taken into account while converting to constant prices. Recovered damages of each individual sample units are deflated by relevant mid-year indices. For example, the damage figures for those who have recovered over a period of 12 months, say, are deflated by relevant bi-annual deflators. Four types of deflators at the national level are constructed - deflators for building materials, national income, manufacturing and wages (Table C3). Deflators for building materials are used in converting structural damages to constant prices; the national income deflators are used in the damage to inventories, machinery and incomes; deflators for manufacturing are used to stock (input and output) damages of industrial and business enterprises; clean-up costs are converted to constant prices deflated by wage indices. The data collected during Oct-Nov (1993) for a flood in Bahubal, which occurred at the of end July (1993) is not deflated. The damage values for those who have not yet recovered fully or not yet recovered at all, are hypothetically estimated based on 1992-93 prices.

Table C1: Hypothetical scenarios in three different floods

Study area	Flood type	Scenario	Depth (ft)	Duration (days/hrs)	Damage factors
Tangail	1988 river flood	1	2	7 days	inundation
		2	2	14 days	
		3	4	7 days	
		4	4	14 days	
Bahubal (Sylhet)	Flash flood	1	1	2 days	inundation Velocity
		2	1	4 days	
		3	2	2 days	
		4	2	4 days	
Khatunganj (Chittagong)	Tidal flood	1	2	6 hrs	Inundation Velocity Storm Salt
		2	4	6 hrs	
		3	6	6 hrs	

Table C2: Time of flood and field work and reference year

Study area	Time of Field work	Flood time	Nearest reference year for data collection
Tangail	July-Sept 1993	September 1988	1987-88
Bahubal Habiganj	Oct-Nov 1993	July 1993	1992-93
Khatunganj Chittagong	Nov-Dec 1993	April 1991	1990-91

Table C3: Deflators used to convert damage values to constant 1992-93 price

	Deflator 1	Deflator 2	Deflator 3	Deflator 4
Year	Construction (building materials)	National income	Manufacturing	Wage
1992-93	100	100	100	100
Mid 91-92	99.11	98.53	98.84	98.84
1991-92	98.21	97.06	97.69	96.69
Mid 90-91	94.34	95.63	95.66	95.66
1990-91	90.47	94.19	93.64	93.64
Mid 89-90	88.39	92.87	89.28	89.39
1989-90	86.31	91.55	84.91	85.13
Mid 88-89	83.64	90.84	81.72	83.36
1988-89	80.96	90.12	78.53	81.58
Mid 87-88	77.98	85.64	75.80	78.66
1987-88	75.00	81.15	73.06	75.73

Source: BBS, Various Issues

APPENDIX D

PROBABLE COST OF PROTECTION FOR TANGAIL TOWN

Having assessed the costs of flooding (vis-a-vis the benefits of flood protection) it would be interesting to obtain an idea of the probable cost of an embankment around Tangail town. Given that this relates to engineering and hence is beyond the scope of the present study, some cost information only in crude form are collected for a preliminary comparison with the benefits of protection. The major source of the information is the Compartmentalization Pilot Project (CPP, FAP-20), Bangladesh Water Development Board, Tangail, the project which is responsible for the work of constructing embankments in its various compartments.

The cost of the embankments surrounding the town vis-a-vis the municipality area is based on some assumptions. The costs of earth work and land acquisition are likely to considerably vary depending on the locations concerned. However, price quotations from two contractors engaged in the embankment construction under CPP at two locations are compiled (Table D1). The estimate of land cost, which is expected to vary even more, is based on the Project Proposal of CPP, which considers 11 land acquisition cases (Table D2). Obviously, this has incorporated diverse land qualities at various locations. So far as the cost of culverts is concerned, a typical actual construction (having standard span specification) carried out by the CPP is considered (Table D3). However, the current estimate of the culvert construction has not incorporated the cost of any control structures. The ancillary costs such as supervisory and over-heads are postulated to be approximately 25% of the total costs. The following specifications (as adopted by CPP) are taken into account while making the estimate:

a Price = 1992-93 price

b Width = 4.27 metre (14 feet)

c Height = 3.05 metre (10 feet)

d Slope = 1:2 (country side), 1:3 (river side)

e Borrow pit = 15.24 metre (50 feet), both sides.

f Culvert span = 3.05 (10 feet)

g Standard of Protection = 1 in 20 years flood.

The length of the proposed embankment surrounding the municipal town area is estimated at 30 Km[1]. A 20 year standard of protection requires an average embankment height of 3.05 metres, and a 40 year standard requires an embankment height of approximately 3.35 metres. Two culverts at each kilometre interval along the embankment are envisaged.

Based on the above assumptions, per Km cost of embankment estimates as TK 5.79 Million and TK 6.21 Million for a 20 and 40 year standard of protection respectively. The total cost of the embankment is estimated as TK 173.7 Million and TK 186.3 Million for the 20 and 40 year standard respectively. The cost break down is shown in Table D4. It needs to be emphasised that the estimated cost is preliminary in that it is based on several assumptions that may have to be modified in a real situation[2]. Importantly, the estimate has not incorporated two cost components, a) operation and maintenance costs and b) the cost of constructing a new drainage system. The components may involve major costs. Hence, the estimate is extremely preliminary which needs to be treated with caution.

Table D1: Estimated cost of earth work (based on two sample construction)

	Earth work for	Length (Km)	Cost (Mil TK)	Contractor
1	Fatehpur Advance Embankment (Earth work only)			
	Km 0.000 - 1.196	1.196	.838	Santush Kumar
2	Saleque Nathkhola Embankment (Bangra)-Earth work only.			
	Km 1.247 - 1.750	.503	.707	Porag Builders

Total earth work for 2 sample cases = 1.017 Km
Total cost(Mil TK)= 1.763
Average per Km cost of earth work = 2.08 Mil Tk
(assuming 20% for compacting)

---

[1] Reading on the Autometre on the map (1:8000) = 370 cm; hence, the periphery is approximately 3000000 cm = 30 Km.

[2] For example, the embankment in the real situation may not require to be constructed around the boundary of the municipality.

Table D2: Cost of land acquisition

As per CPP Project Proposal for land acquisition,
quantity of land proposed to be acquired for CPP = 190 Hectare

Estimated cost at 1992-93 price = 36.9 Mil Tk

Per Hectare cost of land acquisition = 0.194 Mil Tk

Per Km (48.78 metre width) cost of land accusation =
(as per design shown in Figure D1)

= 0.946 Mil Tk
(1 Km embankment requires 4.878 Hectare of land acquisition)

Table D3: Average cost of a culvert

Charpara culvert (work done by Huq Enterprise)
= 0.801 Mil Tk

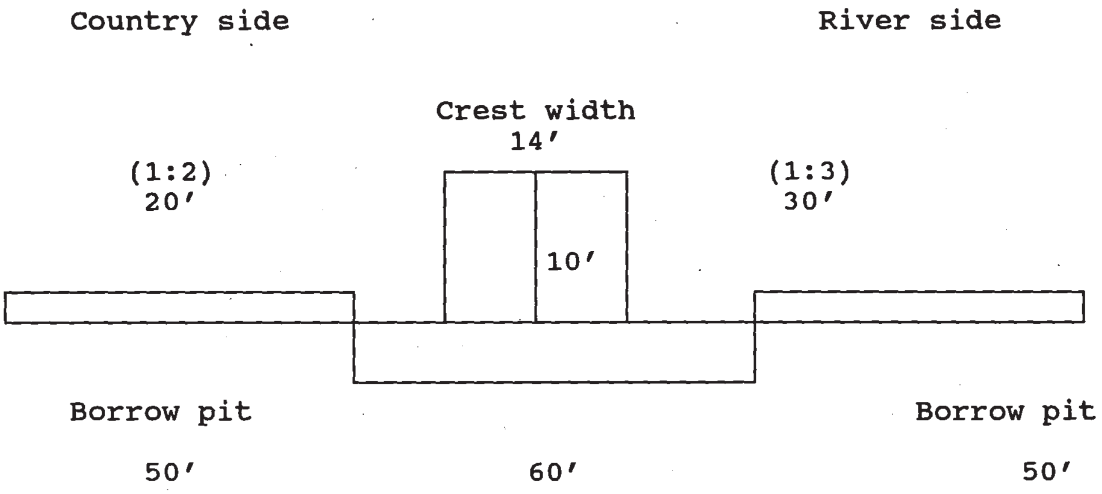
Average cost per Km = TK 1.60 Mil per (@ 2 culverts each Km)

Table D4: Probable cost (per Km) of protection for Tangail town

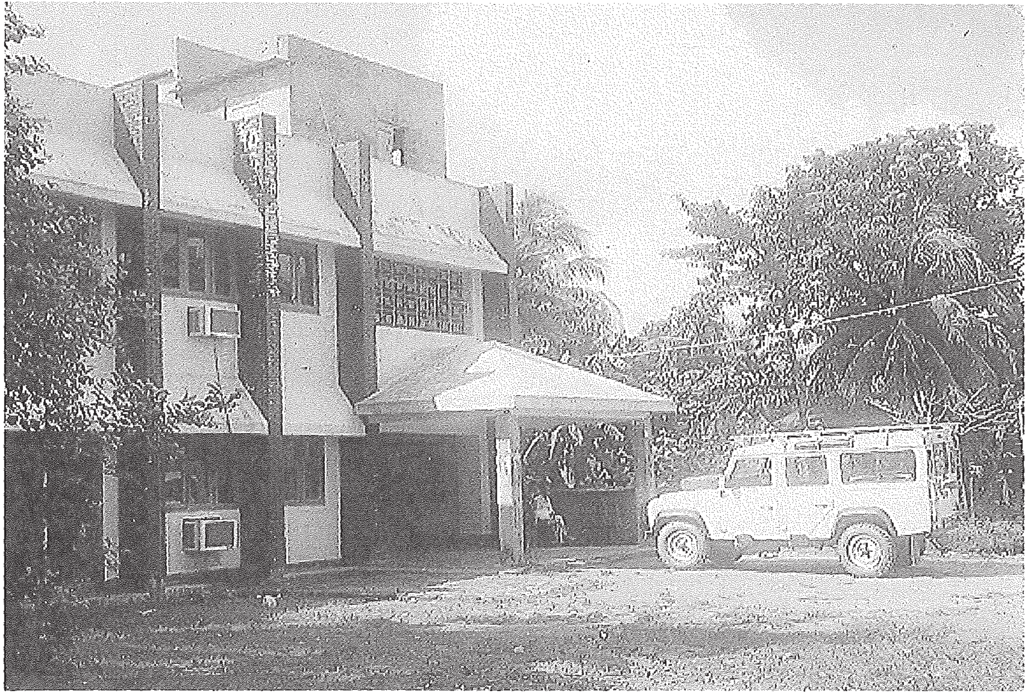
Value in Million Taka (£ = TK 65, approximately)

	Work	Cost of construction for 20 year standard	 40 year standard
1	Earth work per Km	2.08	2.29
2	Cost of land per Km	0.95	1.08
3	Cost of culvert (two each Km)	1.60	1.60
4	Ancillary & overhead (25%)	1.16	1.24
	Per Km cost	5.79	6.21
	Total cost (30 Km embankment)	173.7	186.3

Figure D1: A Hypothetical Embankment Design Specification for a 20 Year Flood



APPENDIX E: PLATES

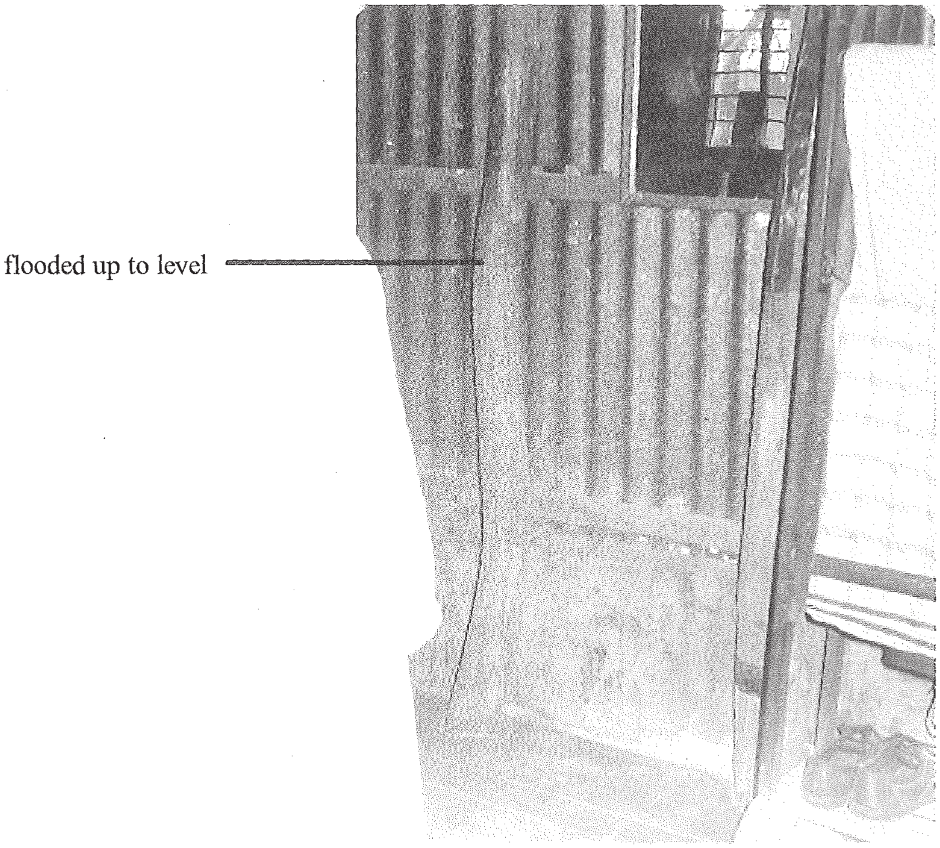


(a) A two-storied BB (brick floor, brick wall) house (Tangail)

(b) A one-storied BB (brick floor, brick wall) house (Tangail)

Plate E:1 : BB (brick floor, brick wall) house

(a) A BC (brick floor, corrugated iron (CI) sheet wall) house (Tangail)

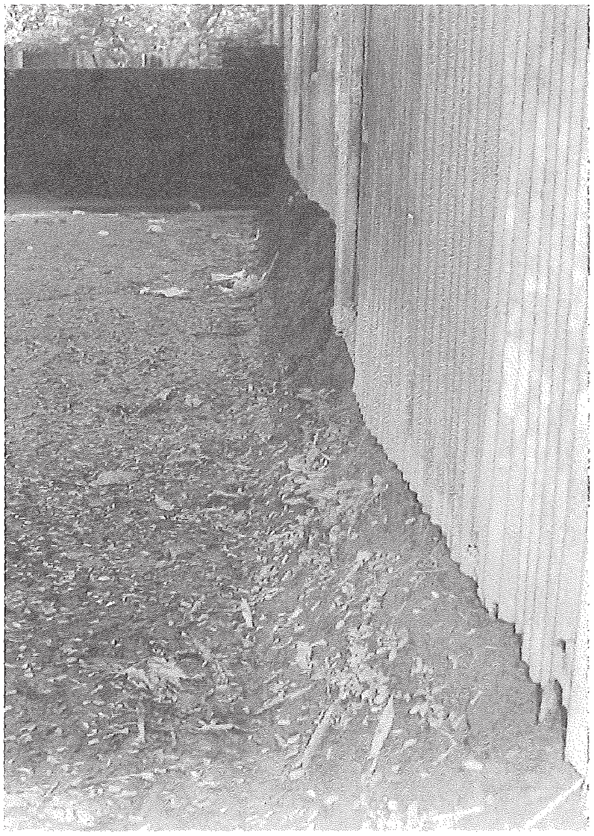


(b) Inside a BC house affected by 1988 flood (Tangail)

Plate E:2 : BC (brick floor, CI sheet wall) house

APPENDIX E:2

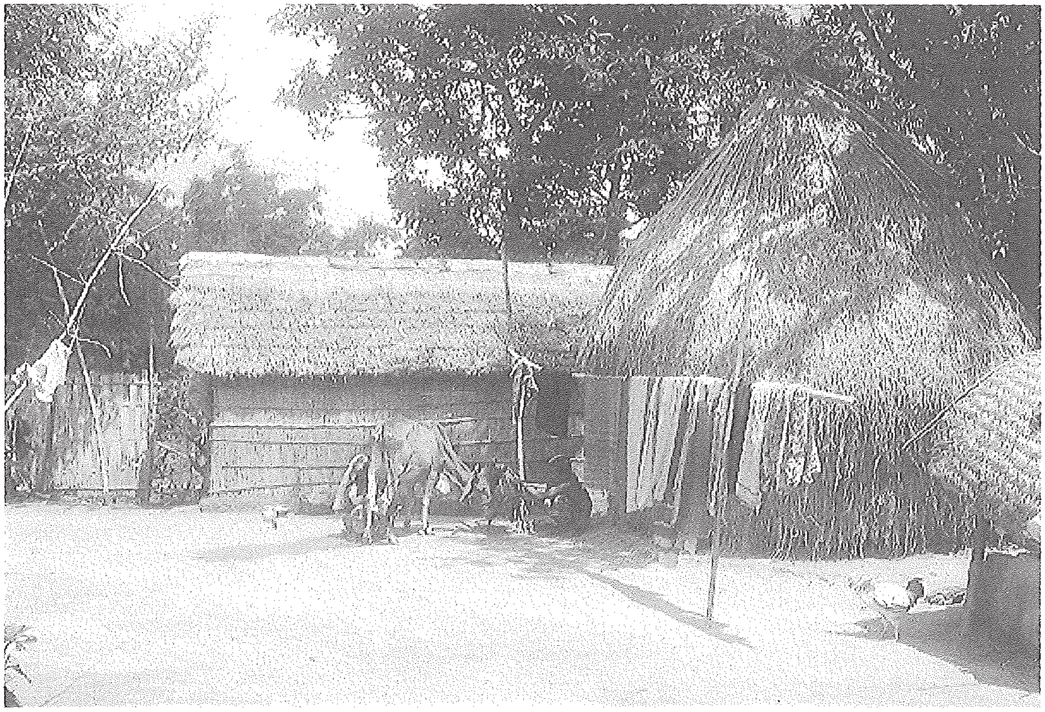
(a) An MC (Mud floor, CI sheet wall) house flooded by 1988 flood (Tangail)



(b) Outside an MC house, outside wall decayed after 1988 flood (Tangail)

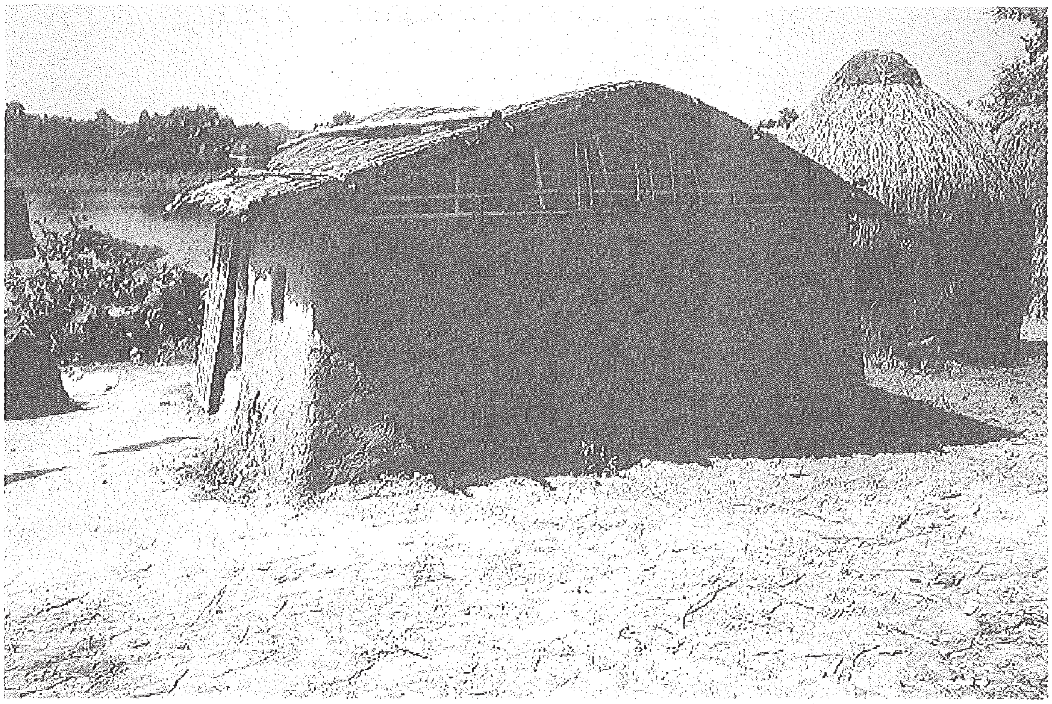
Plate E.3 : MC (mud floor, CI sheet wall) house
APPENDIX E:3

(a) An MT (mud floor, thatched wall) house with CI sheet roof - Tangail



(b) An MT house with thatched roof - Tangail)

Plate E.4 : MT (mud floor, thatched wall) house
APPENDIX E:4

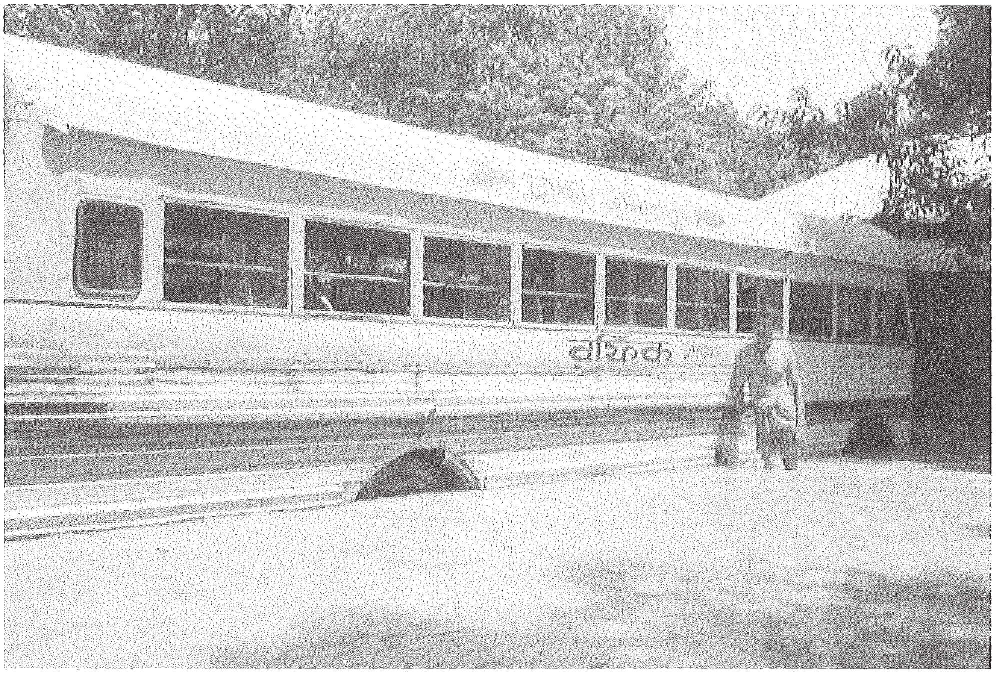


(a) An MM (mud floor, mud wall) house with thatched roof

(b) An MM house with CI sheet roof

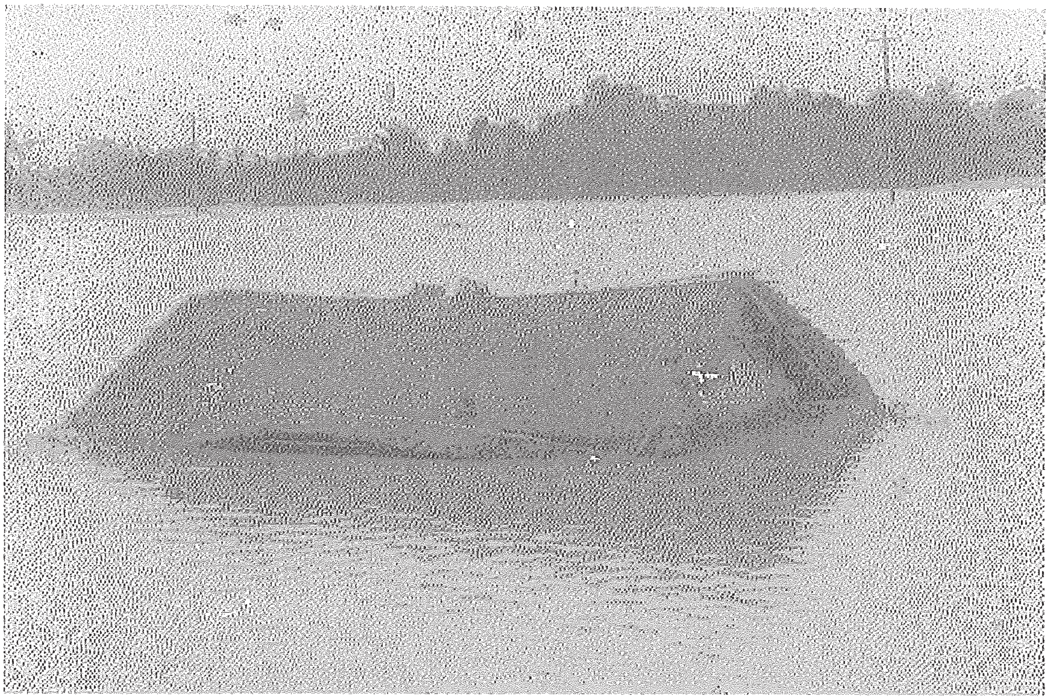
Plate E.5 : MM (mud floor, mud wall) house

(a) A public building (Tangail)



(b) A public transport flooded in 1988 (Tangail)

Plate E.6 : A Public building; a public transport flooded in 1988 flood
APPENDIX E:6



(a) An MT house flooded up to roof (1988 flood-Tangail)

(b) A roof (MT house) being transported to safer pace by boat

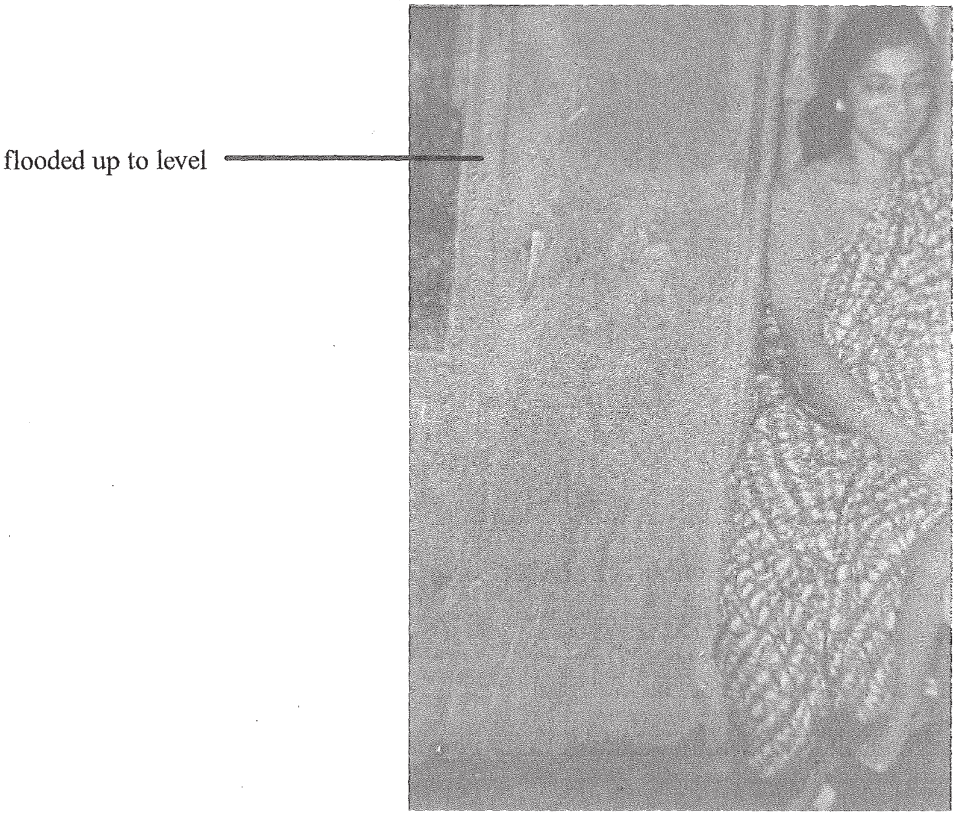
Plate E.7 : An MT house flooded; a roof being transported by boat

(a) A BC house with wall and floor decayed subsequently (1988 flood) - not yet repaired

(b) A brick floor damaged subsequently after 1988 flood - not yet repaired

Plate E.8 : A BC house with wall and floor damaged subsequently

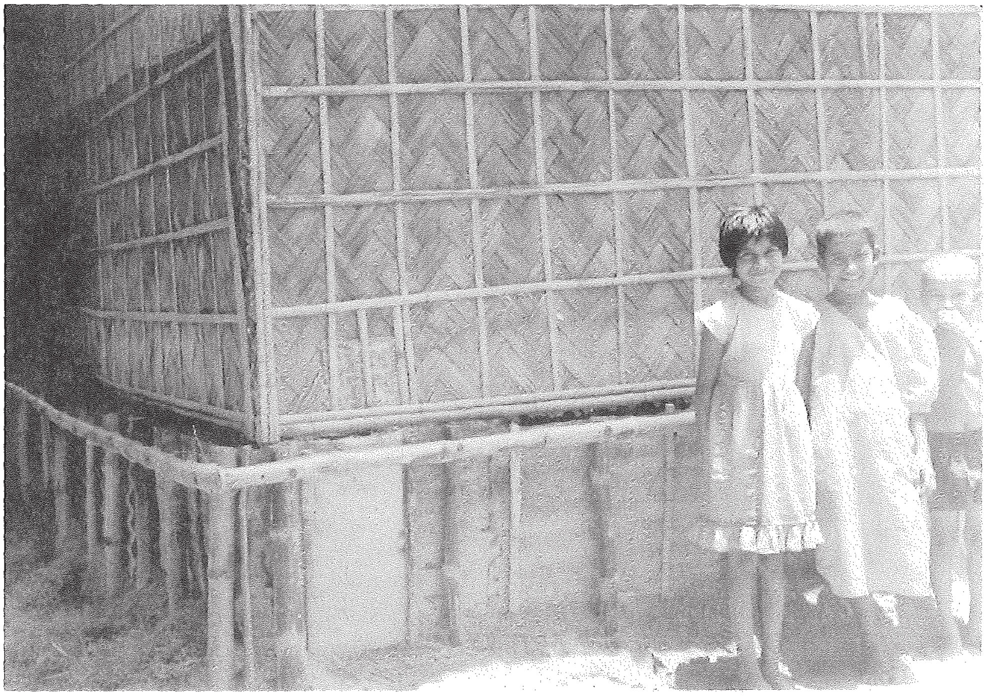
(a) An MM house completely destroyed by flood



(b) A steel wardrobe (flooded up to 1.2 metre) decayed subsequently (1988 flood-Tangail) - not worth repairing any more

Plate E.9 : An MM house destroyed; a wardrobe badly damaged by flood

(a) Flood wall given at the gate of a BB house (1988 flood)



(b) Flood proofing up to a plinth level in an MT house after 1988 flood (Tangail)

Plate E.10 : Flood wall and flood proofing

APPENDIX E:10

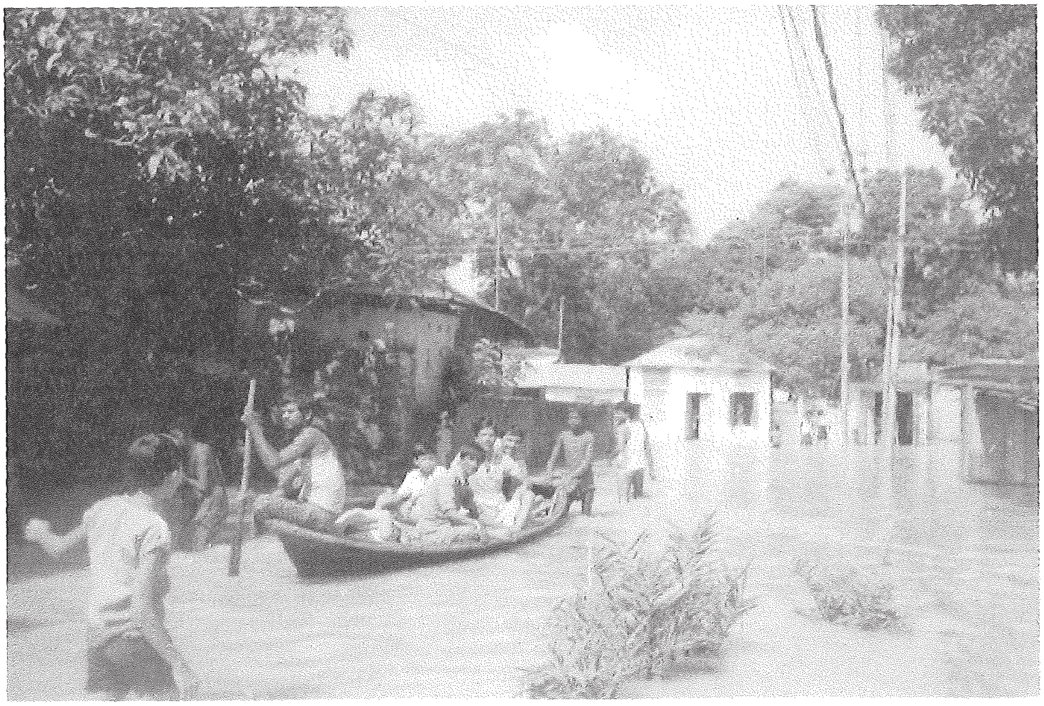
(a) New industries in Tangail are constructed at safer levels after 1988 flood

(a) New houses, too, are constructed at safer levels after 1988 flood in Tangail

Plate E.11 : New industries and houses built at safer levels after 1988

APPENDIX E:11

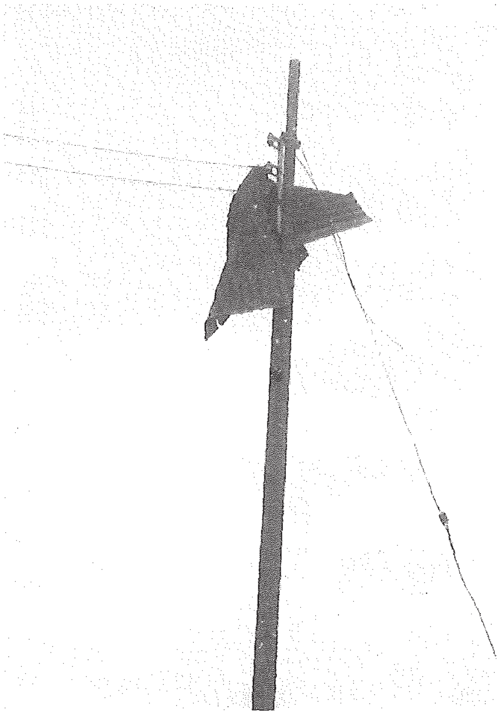
(a) Evacuation through boats (1988 flood, Tangail)



(a) Evacuation through boats (Flash flood, Bahubal 1993)

Plate E.12 : Evacuations during floods

(a) Huge destruction to houses caused by tidal surge and cyclone (1991)



(a) Roof of a MC house blown to a light post by cyclone (1991)
(By curtsey Mr Manjur Kader Manju)

Plate E.13 : Destruction to houses by storm and tidal surge
APPENDIX E:13

a) & b) Children and women appeared to be relatively more vulnerable to tidal surges (1991)

Plate E.14 : Vulnerability of children and women to tidal surges (1991)

APPENDIX E:14

APPENDIX F

SURVEY INSTRUMENT - HOUSEHOLD

The Impacts of flooding and Methods of Assessment in Urban Areas of Bangladesh

Bangladesh Institute of Development Studies, Dhaka
Flood Hazard Research Centre
Middlesex university, UK

HOUSEHOLD SURVEY
QUESTIONNAIRE

For office use only (This questionnaire relates to 1988 flood)

Tangail - major river flood (1988)
Bahubal - flash flood (1993)
Khatunganj - tidal flood (1991)

Identification no ____________________

Interview date ____________________

Interviewer name ____________________

Checked by ____________________

Location/Study area____________________

(TO KEEP INSTRUCTION MANUAL DURING INTERVIEW,PLEASE)

(TO BE READ OUT TO RESPONDENT)

We are carrying out a research on impacts of flooding in urban areas of Bangladesh for Bangladesh Institute of Development Studies (BIDS) and Flood Hazard Research Centre at Middlesex University,UK.The aim of the research is to look into urban and non-agricultural impacts caused by flooding,and their methods of assessment.It is also interesting to know how people,in general, react to flooding in urban areas.The survey is completely confidential;the names and views of individuals participating will not be revealed to anyone and the survey information will be used only in generating some unidentifiable statistical tables.All cooperation and help in this regard will highly be appreciated.

GENERAL INFORMATION

1 Name of head of household ____________________

2 Father's name __________________________

3 Name of respondent ____________________
(if different from head)

4 (a) Sex of the respondent

M	1
F	2

(b) Literacy level

Literate	1
Illiterate	2

5 Address (holding no/street) ____________________

CHARACTERISTICS OF HOUSE (1988)

6 Type of dwelling

(a) Wall materials mainly made of

Straw/bamboo	1	
Mud	2	
CI sheet/wood	3	
Concrete/brick	4	
Others	5	specify _________

(b) Floor of ground floor mainly made of

Mud	1	
Concrete/cement	2	
Others	3	specify ________

(c) Roof mainly made of

Straw/bamboo	1	
CI sheet/wood	2	
Concrete/brick	3	
Others	4	specify ________

7 (a) Total length of outer walls ______(ft)

(b) Total length of internal walls ______(ft)

(c) Age of the main part of the building (1988)

-5 years	1
6-10 years	2
11-20 years	3
21-50 years	4
>50 years	5

8 External condition (through visual assessments)

Poor	1
Fair	2
Good	3

9 Are you the owner of this house?

Yes	1
No	2

10 Since when have you lived in this house?

Year ______

11 Area and storeys occupied by the household

		Now	1988
(a)	No of buildings on site	______	______
	For main building		
(b)	Number of storeys	______	______
(c)	Area of ground floor (sq ft)	______	______
(d)	Area of upper floor (sq ft)	______	______
(e)	Area of open space(sq ft)	______	______
(f)	Area of total premise(sq ft) (all buildings)	______	______
(g)	Area of ceiling space(sq ft)	______	______

12 What was the approximate market value of this property in the condition as existed in 1988?

Ground floor (Tk) (only building) ________

FLOOD EXPERIENCE

13 How many times has this house (inside house) been flooded since your living here?

____

The 1988 flood

14 (a) What was the maximum depth of flood water (above floor) of your property) in the 1988 flood?

________ (inches)

(b) How long did the flood water stay inside your house?

________ (days)

(c) What was the floor height of your property (w.r.t.ground level) at the time of the 1988 flood?

_________ (inches)

(d) Have you raised the floor height since the 1988 flooding?

Yes	1
No	2

(e) If YES, what is the present floor height?

_________ (inches)

(f) Did you undertake any other measures (since the 1988 flood) in order to prevent flooding in your house?

Yes	1
No	2

(g) If YES, what
(Record verbatim)

____

____

FLOOD DAMAGE-DIRECT

A HOUSE STRUCTURE

15 Threshold of depth and duration

(a) At what height above floor level does flood water start to damage your property (however short, the duration of flooding is)?

(i) For house structure _____ (inches)

(ii) For inventories _____ (inches)

(b) For how many days does your property have to be flooded inside before it is damaged (however, minor, the depth of flooding is)?

(i) For house structure _____ (days)

(ii) For inventories _____ (days)

16 Did the 1988 flood cause any damage, however minor, to the structure of your building ?

Yes	1
No	2

If YES,
17 What was the value of the damage to?

(a) Floor Amount (Tk) __________

(b) Wall Amount (Tk) __________

(c) Roof Amount (Tk) __________

(d) Boundary wall Amount (Tk) __________

(e) Installations	Amount	
Gas	____	(TK)
Electricity	____	(TK)
Water	____	(TK)
Others	____	(TK)
(f) Total	____	(TK)

18 Have there been any subsequent problems with the structure of the house? (PROBE:Subsidence,damp,rotting of wood works)

Yes	1
No	2

If YES,
What kind of problem (Record verbatim)?

____

____

19 Of all your building repairs undertaken, did you do all such works yourself or did you pay workman to do it ? What were the individual contributions? (Ask by each components 17a,b,c,d,f and then add up)

	Yes	No	NA	%	NA
Yourself	1	2	-8	_	-8
Hired	1	2	-8	_	-8

20 (a) Have you fully accomplished repair and replacement of your damages caused by the flood?

Yes	No	NA	% Recovered	NA
1	2	-8	___	-8

(b) How long did it take to do this work which you have recovered?

Recovery period (Months) _______

(c) If not yet fully recovered, how long would you expect it would further take to complete the remaining repair work of the 1988 flood damages?

Months	_______
NA	-8
Not sure	-9

(d) Can you tell us why the reconvey has taken so long (if it is so)? (Record verbatim)

____

____

____

B CLEAN-UP COST

21 How long did it take to get the house clean after the 1988 flood?

Days ____

22 After the flood was over, did you do the clean-up works yourself or did you pay workmen to do it ?

Self/family member	1
Hired	2
Mixture	3
NA	-8

23 What was the additional time spent on clean-up work (additional to repair work)? Could you estimate how much the clean-up cost was on account of:

		Person days	Cost TK	NA
(i)	Self/family member	_____	____	-8
(ii)	Hired	_____	____	-8
(iii)	Total	_____	____	-8

C INVENTORY

24 Did you <u>own</u> any of the following items at the time of the 1988 flood? What were their <u>values</u> then? If an item was damaged by the flood what was the <u>value of damage</u> (cost of repair or replacement as already carried out by you, and the work remained to be done)?

<u>Domestic</u>	Number owned	Value	Damage value
Radio			
Television			
Refrigerator			
Video player			
Tape recorder			
Video/Tape cassette			
Electric iron			
Sewing machine			
Cutlery			
Utensil			
Stove/cooker			
Others			
SUB-TOTAL			

<u>Furniture</u>	Number owned	Value	Damage value
Show case(wood)			
Sofa set(wood)			
Book shelf(wood)			
Carpet			
Mat			
Chest of drawers(wood)			
Chest of drawers(steel)			
Almirah(wood)			
Almirah(steel)			
Dinning table(wood)			
Dinning chair(wood)			
Dressing table(wood)			
Bed-single(wood)			
Bed-double(wood)			
Reading table(wood)			
Reading chair(wood)			
Garden table(wood)			
Garden chair(wood)			
Garden chair(steel)			
Curtains			
Others			
SUB-TOTAL			

<u>Transport</u>	Number owned	Value	Damage value
Boat			
Cart			

Bicycle
Rickswa
Auto-rickswa
Motor cycle
Car/bus/truck
Others

SUB-TOTAL

Personal effects	Number /quantity	Value	Damage value
Clothing			
Books			
Ornaments			
Cosmetics			
Stock of food etc			
Others			

SUB-TOTAL

GRAND TOTAL
(To be calculated later)

25 I would now like you to think about possible floods in the future. Based on your 1988 flood experience, could you estimate what would be the potential cost of damage to each of the following components in the event of four hypothetical flood scenarios mentioned below? (% of value with respect to 1988 flood damage)

(Note: The 1988 flood may match with one of the following flood scenarios- first identify that,and then proceed to estimate in other three scenarios- refer to Q 17, 23, 24).

(a) <u>House structure</u>

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	—
2	2	14	—
3	4	7	—
4	4	14	—

Code 1988 scenario = 100

(b) Clean-up costs

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	_
2	2	14	_
3	4	7	_
4	4	14	_

Code 1988 scenario = 100

(c) Inventory damage

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	_
2	2	14	_
3	4	7	_
4	4	14	_

Code 1988 scenario = 100

26 (a) Did you lose any thing which is impossible to replace?

Yes	1
No	2

(b) If YES, what

Items		Yes	No	NA
(i)	Photo	1	2	-8
(ii)	Certificates	1	2	-8
(iii)	Documents	1	2	-8
(iv)	Antiques	1	2	-8
(v)	Others	1	2	-8

D HEALTH AND STRESS

27 (a) Do you think that the flood affected your health or that of any member of your family?

Yes	1
No	2
Not sure	8

If YES,
(b) How many members of your household were affected?

______ Nos

(c) What were the problems? How serious were the effects? Scale your effects starting from 0 (no effects) to 5 (maximum effects) on the following effects:

0 1 2 3 4 5

(i) Diseases broke out	(code 0-5) __
(ii) Mental stress and depression	(code 0-5) __
(iii) Injuries	(code 0-5) __
(iv) Others	(code 0-5) __

28 (a) During the flood or soon after were there any deaths in your family which you think were directly or indirectly due to the flood ?

Yes	1
No	2

(b) If YES, number of such deaths

_____ Number

(c) Please give details of any such deaths

____

____

29 (a) Compared to the period 6 months before the 1988 flood, do you think that the cost of medical expenses in your family during and 6 months after the flood was

Same	1
Higher	2
Lower	3

(b) What was the percentage difference,if any, compared to before the flood?

_____ (%)

(c) What was the average monthly cost of medical expenses in your household at normal time?

_____ (TK)

30 Here are some statements that people often make about a flood. Do you agree or disagree with them?

Agree - 1 Disagree - 2 Not sure - 3

1 We are used to floods and so we hardly worry about their occurrence ___

2 We are very worried when it rains heavily ___

3 We are afraid when a storm is forecast ___

4 When it rains heavily we check the level of water in the rivers ___

5 We begin to worry when flooding takes place in other parts of the country ___

6 We very much worry when flooding starts in the neighbouring areas ___

7 We keep stocks of fuel,dry food and others when we apprehend the possibility of a flood___

8 We feel there is nothing we can do and it is an act of Allah, and we must live with that ___

31 Were there any other effects upon your household which we have not discussed?

Yes	1
No	2

If YES, what are those?

Item		Value (TK)	Damage value (TK)
(i)	Trees, fruit tress	______	______
(ii)	Livestock,Poultry fishery	______	______
(iii)	Others/other house	______	______

32 In summary, how great a risk (effects) to health and your property do you think there is from flooding in this locality? (code 0, for no risk; to 5, for very high risk)

(a) Health

__________________ code 0-5 ___
0 1 2 3 4 5

(b) Property

____________________ code 0-5 ___
0 1 2 3 4 5

WARNING

33 (a) During the flood of 1988 were you warned of the possibility of flooding?

Yes	1
No	2

If YES,
(b) Were you warned about the possibility of flood by any of the following?

	Yes	No	NA
Water Development Board	1	2	-8
Ministry of Flood	1	2	-8
Chamber of Commerce	1	2	-8
Other govt dept.	1	2	-8
Police	1	2	-8
Local authority	1	2	-8
Municipality	1	2	-8
District official	1	2	-8
UZ/Thana authority	1	2	-8
Red Cross	1	2	-8
Media(Radio/Television	1	2	-8
Others (specify)	1	2	-8

(c) What was your reaction when you received the message of warning?

Believed the message	1
Didn't believe at all	2
Not certain	3
Don't know	4
NA	-8

34 How many hours before flood water entered your property were you warned?

Before ______ (hours)

NA -8

Perception (informal warning)

35 Irrespective of any official warning given, were you able to perceive that flooding was going to occur?

Yes	1
No	2

If YES,

36 How did you become <u>aware</u> of the possibility of flooding? (mention three most important sources)

Through

Reading news paper	1
Excessive rainfall	2
Flooding in neighbouring areas	3
Rising level of nearby rivers	4
Message from friends/relatives	5
Impression from elderly people	6
Migration of rats	7
Others (specify)...........	8
Not applicable	-8

37 How many hours before it happened, did you <u>realise</u> that the flooding is going to happen at your site?

_______ (hours)

38 Have you any idea of how many hours after the flood water entered into your town did it take to <u>start entering</u> into your own property?

_______	(hours)
N A	-8

<u>Loss adjustment and social links</u>

39 (a) What proportion of the total value of your house contents were at risk? (Ask referring the check list provided in Q 24)

____ (%)

40 (b) As a result of prior awareness about floods either through official or informal warnings, did you take any <u>actions</u> to reduce the potential damages?

Yes	1
No	2

If YES,
(c) Did you <u>move</u> some of your household contents to a safer place ?

Yes	1
No	2

If YES,
(d) What proportion of the total value of house contents at risk did you <u>remove</u>? (Ask referring the check list provided in Q 24)

____ %)

(e) Where did you mainly move these properties?

To

	Yes	N0	%
Within house/building	1	2	_
Own house in this locality	1	2	_
Own house in other locality	1	2	_
Neighbours in this locality	1	2	_
Friends in this locality	1	2	_
Friends in other locality	1	2	_
Relatives in this locality	1	2	_
Relatives in other locality	1	2	_
Public building	1	2	_
Relief camp	1	2	_
Not applicable	-8		

(e) What other actions did you undertake to reduce the potential damages? (Record verbatim)

____

____

(f) Can you estimate the total value of the damages avoided (for contents and others, if any)?

_________ (Tk)

41 Could you tell us what your main occupation was during 1988 flood? (code according to occupation code)

Occupation code		Occupation code	
Retailing (owned)	1	Rickshaw puller	14
Retailing (employed)	2	Car/truck driver	15
Wholesaling (owned)	3	Cart puller	16
Wholesaling (employed)	4	Boatman	17
Small industries (owned)	5	Other transport worker	18
S.industries (employed)	6	Cultivation	19
Large industries (owned)	7	Agricultural worker	20
L.industries (employed)	8	Salaried service	21
Contractor	9	Paid domestic work	22
Missionary work	10	Unemployed	23
Carpenter	11	Retired	24
Other non-agr work	12	Housewife	25
Transport business	13	Others (specify) ________	26

42 (a) Did you have any other subsidiary occupations, however minor at that time?

Yes	1
No	2

If YES,
(b) how many?

_____

43 (a) How many members were there in your household living in this house at the time of 1988 flood?

	No	Earner No
Children	__	__
Adults- active	__	__
- disabled	__	__
Total	__	__

(b) Could you tell what was the gross annual income from all sources in your household?

________ (Tk)

44 (a) Did the 1988 flood (and its aftermath) have any impacts (either positive or negative) on the employment/income of any member of your household (including yourself)?

Yes	1
No	2

If YES,

(b) What was the total impact on your household in terms of employment and income?

	Employment P days gained /lost	Income gained /lost(Tk)
All household members (including yourself)		
During flood	_____	_____
After flood	_____	_____

(Gain +ve, Loss -ve)

45 After the 1988 flood, how did you make good your losses caused to your property and/or income?

Support from	Yes	No	%
Government help	1	2	_
Savings	1	2	_
Income of subsidiary occupations	1	2	_
Income from household members	1	2	_
Loans from employer	1	2	_
Loans from institutional sources	1	2	_
Loans from friends/relatives	1	2	_
Reducing consumption(basic commod)	1	2	_
Reducing consumption(luxury commod	1	2	_
Insurance	1	2	_
Others	1	2	_
Not applicable	-8		

46 Do you think that immediately after the flood in your town, as a short term effect, your

(a) Employment opportunities

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9) ____

(b) Income

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9) ____

(c) Consumption of food items

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9) ____

(d) Purchase of industrial items

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9) ____

(e) Prices of food items

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9) ____

(f) Prices of industrial items

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9) ____

(g) Wage rates in agricultural activities

Remained same (code 0) ____
Declined (%) ____
Increased (%) ____
Not sure (code -9)

(h) Wage rates in industrial activities

Remained same	(code 0)	____
Declined (%)		____
Increased (%)		____
Not sure	(code -9)	____

47 It is often said that traders and businessmen use the abnormal flood situation to hoard and artificially create shortage of necessities in order to make exorbitant profits.

How strongly do you agree or disagree with this statement in relation to 1988 flood? Please indicate by scaling your opinion as total agreement (coding 5) to total disagreement (coding 0).

Totally disagree 0 1 2 3 4 5 Totally agree

Evacuation

48 During or after the 1988 flood did you or any member of your household evacuate your house for a safer place?

Yes	1
No	2

If YES,
(a) Who moved to a safer place?

Whole family	1
All except yourself/H head	2
Few members	3

(b) For how long?

______ (days)

(c) Which was the main place moved to?

Own house in other locality	1
Own house in this locality	2
Neighbours in this locality	3
Friends in this locality	4
Friends in other locality	5
Relatives in this locality	6
Relatives in other locality	7
Public building	8
Relief camp	9
Not applicable	-8

49 (a) During the flood did you <u>help</u> anyone with evacuation or other relief operations?

Yes	1
No,I was too busy with my own affairs	2
No, I was not fit enough	3
No, no need arose	4

If YES,
(b) Who did you help ?

	Yes	No
Relatives of same 'bari'	1	2
Relatives of other 'bari'	1	2
Relatives within 'gusti'	1	2
People who worked for you	1	2
Friends	1	2
Neighbours	1	2
Unknown people	1	2

(c) What type of help did you give?

	Yes	No
Moving people or lifting goods	1	2
Treating sick and ill	1	2
Providing shelter in my home	1	2
Providing food to victims	1	2
Organising relief for distress	1	2
Cleaning up victim's house	1	2
Financial help	1	2
Others	1	2
Not applicable	-8	

(d) Did you <u>receive</u> any help/support from others?

Yes	1
No	2

If YES,
(e) What type of help/support received?

	Yes	No
In moving my family/goods	1	2
In receiving medical help	1	2
Shelter in others home	1	2
In receiving food	1	2
In clean-up work	1	2
Financial help	1	2
Others	1	2
Not applicable	-8	

(f) Do you think, compared to normal time, <u>community spirit</u> during floods becomes

Heightened	1
Lessened	2
Same	3
Not sure	-9

(g) During the 1988 flood if you had helped the flood victims in their evacuation or relief operations what <u>motivated</u> you to do so?

	Yes	No
Moral satisfaction	1	2
Social obligation	1	2
Religious duty	1	2
Political objective	1	2
Commercial gain	1	2
Not sure		-9

(h) If you <u>were</u> in a flat in a multi-storeyed building would you be prepared to help the households residing in the ground floor during floods?

Yes, certainly	1
Yes, possibly	2
Not really	3
Not sure	-9

If YES,

(i) What type of help are you prepared to offer?

	Yes	No
In keeping goods in my house	1	2
Shelter to household members	1	2
In providing food	1	2
In cooking food for them	1	2
Others(specify)______	1	2

(j) In the 1988 flood, <u>did</u> the residents of upper floors <u>come forward</u> in helping out the ground floor occupants ?

Yes, all	1
Yes, many	2
Yes, some	3
Very few	4
None	5
Not aware	-9

(k) During the last 1988 flood what, in your opinion, was the <u>role</u> of the relatively richer and more <u>affluent</u> sections of the society living in this area?

Did their best to help	1
Offered limited help	2
Rarely came forward	3
Did not come forward at all	4
Not sure	-9

50 (Applicable: Q (a & b) for 1993 flash flood; Q(a, b, c & d) for 1991 tidal flood)

Now, finally, based on your experience of damages caused to you in the last flood of 1991/1993, could you segregate your total damages (in %) to each of the following items on account separately of Inundation, water Velocity, Storm and Salinity:

	% Damage to		
	H Structure	Inventory	Others
(a) Inundation alone (normal velocity)			
(b) Velocity of water			
(c) Stormy wind			
d) Salt contamination			

THANKS FOR YOUR ALL HELP AND CO-OPERATION.

APPENDIX G

SURVEY INSTRUMENT - BUSINESS AND INDUSTRIAL ENTERPRISE

The Impacts of flooding and Methods of Assessment in Urban Areas of Bangladesh

Bangladesh Institute of Development Studies, Dhaka
Flood Hazard Research Centre
Middlesex university, UK

BUSINESS AND INDUSTRIAL ENTERPRISE
SURVEY QUESTIONNAIRE

For office use only (This questionnaire relates to 1988 flood)

Reference floods:

Tangail - major river flood (1988)
Bahubal - flash flood (1993)
Khatunganj - tidal flood (1991)

Identification no __________________

Interview date __________________

Interviewer name __________________

Checked by __________________

Location/Study area __________________

(TO KEEP INSTRUCTION MANUAL DURING INTERVIEW,PLEASE)

(TO BE READ OUT TO RESPONDENT)

We are carrying out a research on impacts of flooding in urban areas of Bangladesh for Bangladesh Institute of Development Studies (BIDS) and Flood Hazard Research Centre at Middlesex University,UK.The aim of the research is to look into urban and non-agricultural impacts caused by flooding,and their methods of assessment.It is also interesting to know how people,in general, react to flooding in urban areas.The survey is completely confidential;the names and views of individuals participating will not be revealed to anyone and the survey information will be used only in generating some unidentifiable statistical tables.All cooperation and help in this regard will highly be appreciated.

GENERAL INFORMATION

Enterprise

1 (a) Name of the enterprise

____

(b) Address ________________________________

(c) Type of business/activity ____________________
(give details)

____

____

(d) Respondent's position

Proprietor	1
Manager	2

(d) Respondent's literacy level

Literate	1
Illiterate	2

FLOOD EXPERIENCE

2 (a) Does this business <u>own</u> the premises?

Yes	1
No	2

(b) How many years has this business/activity been carried out in this <u>premise</u>?

________ Years

(c) How many times has this site (not necessarily inside the main building) been flooded in the last 10 years (or since you started business here,if less than 10 years)?

____

1988 Flood

3 (a) What was the maximum <u>depth</u> of water in the 1988 flood (w.r.t. floor level of your property)?

________ (inches)

(b) How long did the flood water <u>stay</u> inside your property?

________ (days)

(c) What was the floor height of your property (w.r.t.ground level) at the time of 1988 flood?

_______ (inches)

(d) Have you raised the floor height since the 1988 flooding?

Yes 1
No 2

If YES,
(e) what is the present floor height?

_______ (inches)

(f) Did you undertake any other measures in order to prevent flooding in your premise?

Yes 1
No 2

If YES, what
(Record verbatim)

____

____

BUILDING AND STRUCTURE

		NOW	1988
4	Area and number of storey		
	(a) No of buildings on site	_______	_______
	For main building		
	(b) Number of storeys	_______	_______
	(c) Area of ground floor (sq ft)	_______	_______
	(d) Area of upper floor (sq ft)	_______	_______
	(e) Area of open space(sq ft)	_______	_______
	(f) Area of total premise(sq ft) (all buildings)	_______	_______
	(g) Area of ceiling space(sq ft)	_______	_______
5	Walls (ground floor)		
	(a) Total length of outer walls	_______ (ft)	
	(b) Total length of internal walls	_______ (ft)	

(c) Walls mainly made of (%)

(i) Straw/bamboo _____

(ii) CI sheet _____

(iii) Concrete/brick _____

6 (a) Floors (ground floor) mainly made of

(i) Concrete/cement 1

(ii) Mud 2

(iii) Others (specify) 3 _______

(b) Roof mainly made of

(i) Straw/bamboo _____

(ii) CI sheet _____

(iii) Concrete/brick _____

CAPITAL OUTPUT TURNOVER & EMPLOYMENT

7 What was the approximate value of fixed investment of your business/industry? (building,machinery,equipment and fixtures- not land,situated in ground floor)

(i) Now

(a) Building _______ (Tk)

(b) Machinery/Equipment _______ (Tk)

(c) Others _______ (Tk)

(d) Total _______ (Tk)

(ii) 1988

(a) Building _______ (Tk)

(b) Machinery/Equipment _______ (Tk)

(c) Others _______ (Tk)

(d) Total _______ (Tk)

8 What was your value of working capital (average throughout the year,in the form of stock of inputs, finished and unfinished goods (to exclude credits,cash at hand or bank)?

(i) Now

(a) Stock of inputs ________ (Tk)

(b) Finished, unfinished goods ________ (Tk)

(c) Total ________ (Tk)

(ii) 1988

(a) Stock of inputs ________ (Tk)

(b) Finished, unfinished goods ________ (Tk)

(c) Total ________ (Tk)

9 What was your average monthly value of outputs/turn-over?

Now ________ (Tk)

1988 ________ (Tk)

10 What was your average monthly employment (person days)?

	Person days	
	Now	1988
(a) Family/self	______	______
(b) Hired permanent	______	______
(c) Hired casual	______	______
(d) Total	______	______

11 Could you tell us what were the average wage rates of your workers?

	Wage rate	
	Now	1988
(a) Hired permanent (Tk/daily)	______	______
(b) Hired casual (Tk/daily)	______	______

12 What proportion (%) of your output/turn-over would you estimate is net income?

	Now	1988
Proportion (%)	__	__

DIRECT DAMAGE

1988 flood

A **Building Structure**

13 Was there any direct damage, however minor, to your building structure in 1988 flood?

Yes	1
No	2

If YES,

14 What was the value of the damage to?

(a) Floor Amount (Tk) ____________

(b) Wall Amount (Tk) ____________

(c) Roof Amount (Tk) ____________

(d) Installations

Gas	_______
Electricity	_______
Water	_______
Others	_______
Total	_______

RECOVERY

15 Of all the repairs etc to your building undertaken, did you do all such work yourself or did you pay workmen to do it? What are the respective proportions?

	Yes	No	NA	%
(a) Family/self	1	2	-8	_
(b) Regular worker	1	2	-8	_
(c) Casual worker	1	2	-8	_

16 (a) Have you fully accomplished repair and replacement of your damages caused due to the flood?

Yes	No	NA	% Recovered
1	2	8	______

(b) How long did it take to do the repair work sofar done?

Recovery period (Months) ______

(c) If not yet completed the repair work, how long would you expect it would further take to complete the remaining repair work of the 1988 flood damages?

Months ______
NA -8
Not sure -9

(d) Why did it take so long (if it is so)?
(Record verbatim)

____

____

B Clean-up costs

17 (a) After the flood was over, did you do the clean-up works yourself or did you pay workmen to do it ?

(i)	Self/permanent worker	1
(ii)	Casual hired	2
(iii)	Mixture	3

(b) Could you estimate how much the clean-up operation cost was on account of:

		Person days	Cost Tk	NA
(i)	Self/permanent worker	_	_	-8
(ii)	Casual hired	_	_	-8
(iii)	Total	_	_	-8

(c) How long did it take to get the premises clean after the flood ?

___ (days)

C Machinery and equipment

18 Was there any damage to your:

	Yes	No	Cost(Tk)*	NA
Machinery/Equipment	1	2	_______	-8
Others	1	2	_______	-8
Total	1	2	_______	-8

*COST: See note in Manual.

D Stock damage

19 Was there any damage to your:

	Yes	No	Cost(Tk)	NA
R/M & other inputs	1	2	_______	-8
Unfinished goods	1	2	_______	-8
Finished goods (stock for sale)	1	2	_______	-8
Total	1	2	_______	-8

20 Could you identify any long term direct effects of 1988 flooding on your property as of today? Could you also provide cost estimates in overcoming those effects?

		Yes	No	Cost Code*	Cost (Tk)	NA
(a)	Foundations damaged	1	2	_	_	-8
(b)	Wall cracked	1	2	_	_	-8
(c)	Floor cracked	1	2	_	_	-8
(d)	Roof cracked	1	2	_	_	-8
(e)	Plaster decayed	1	2	_	_	-8
(f)	Painting discol.	1	2	_	_	-8
(g)	C/I sheet rusted	1	2	_	_	-8
(h)	Wood works rotted	1	2	_	_	-8
(i)	Total	1	2	_	_	-8

* Cost code :
Cost not included in previous estimate = 1
Cost included in previous estimate = 2
Cost not incurred (not made good)yet = 3

POTENTIAL DIRECT DAMAGE

Threshold of depth and duration

21 (a) At what height above floor level does flood water start damaging your property (whatever the duration of inundation is)?

(i) For machinery etc _____ (inch)

(ii) For stock _____ (inch)

(b) At what duration of inundation does flood water start damaging your property (whatever the depth of flooding)?

(i) For machinery etc _____ (days)

(ii) For stock _____ (days)

22 I would now like you to think about possible floods in the future. Based on your 1988 flood experience, could you estimate what would be the potential cost of damage to each of the following components in the event of four hypothetical flood scenarios mentioned below? (% of value with respect to 1988 flood damage)

(Note: The 1988 flood may match with one of the following flood scenarios- first identify that,and then proceed to estimate in other three scenarios- refer to Q 14, 17,18,19).

(a) House structure

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	_
2	2	14	_
3	4	7	_
4	4	14	_

Code 1988 scenario = 100

(b) Clean-up costs

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	__
2	2	14	__
3	4	7	__
4	4	14	__

Code 1988 scenario = 100

(c) Machinery and equipment damage

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	__
2	2	14	__
3	4	7	__
4	4	14	__

Code 1988 scenario = 100

(d) Stock damage

(i) raw materials

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	__
2	2	14	__
3	4	7	__
4	4	14	__

(ii) Semi-finished and finished goods

Flood Scenario	Depth (ft)	Duration (days)	% with respect to 1988 flood
1	2	7	__
2	2	14	__
3	4	7	__
4	4	14	__

Code 1988 scenario = 100

INDIRECT DAMAGE (1988 flood)

23 Besides direct damages to your building, plant,machinery etc, did you suffer any disruption to production or business in the 1988 flood?

Yes	1
No	2

If YES,

24 Did the flood result in any time (days) for which your production/business was completely closed (ie when you had no activities at all)?

If YES, for how long?

_____ (days)

25 (a) Could you tell us for how long, if at all, your production/business was partially carried out (ie greater than 0 % but less than 100 %)

_____ (days)

(b) On average during this time, what proportion of your normal production/business were you able to carry out during the period of partial production? (Averaging production from the time when you started production to when you were back to a completely original situation)

_____ (%)

Recovery

26 Could you later on make up some of your business/production lost during the total and partial closure you have just indicated?

Yes	1
No	2

27 If YES,
What was the <u>percentage</u> of total lost production that could be ultimately <u>recovered</u>? And what were the <u>additional costs</u> involved (if any) in the process?

(a)	% lost production recovered	__
(b)	Additional costs (Tk)	__
	Not applicable	-8

<u>Note</u>:Estimate first person-days,overtime etc involved, and later calculate additional cost.

POTENTIAL INDIRECT DAMAGE

28 Based on your experience of 1988 flood you have just indicated, could you estimate what period your production/business would be affected by the following depths and durations?

Flood scenario	Depth (ft)	Duration (days)	Days of closure		Average % during partial production
			Totally	Partially	
1	2	7			
2	2	14			
3	4	7			
4	4	14			

29 Do you think any of the business/production you are likely to lose during the total closure and partial production can be <u>recovered</u>?

Yes 1
No 2

30 If YES,
Please estimate the <u>proportion</u> of otherwise lost business/production that could be <u>recovered</u> in the event of the following depths and duration? And what could be the additional costs involved in the process?

Flood scenario	Depth (ft)	Duration (days)	Possible recovery (%)	Extra costs (Tk)
1	2	7		
2	2	14		
3	4	7		
4	4	14		

Transferability and Dependency

31 Does this enterprise have any other branch/site outside this location for your production/business activities?

Yes	1
No	2

32 If YES, could you transfer any of your disrupted production activities to any of these sites?

Yes	1
No	2

33 If so, what was the percentage of your lost production in this site you were able to transfer to those sites during the 1988 flood?

___ (%)

34 Could you tell us to what extent your buyers are dependent on you? (ie can they easily switch to competitors?)

Now

	Yes	NO	NA
Highly	1	2	-8
Moderately	1	2	-8
Low	1	2	-8
Not at all	1	2	-8

1988

Highly	1	2	-8
Moderately	1	2	-8
Low	1	2	-8
Not at all	1	2	-8

Note: Highly = > 50%, Moderately = 25-50%, Low = < 25%

35 Could you tell us to what extent you are dependent on your existing suppliers of inputs? (ie are there others you could easily transfer to)?

Now

	Yes	No	NA
Highly	1	2	-8
Moderately	1	2	-8
Low	1	2	-8
Not at all	1	2	-8

1988

Highly	1	2	-8
Moderately	1	2	-8
Low	1	2	-8
Not at all	1	2	-8

36 How many days of normal demand could you meet from <u>normal</u> <u>stock</u> if production/purchase is suspended by a flood?

_____ (%)

37 If you could not supply your produce to your customers after a flood, for what proportion would they

(a) Be able to run their business from their stock?

_____ (%)

(b) Buy from your competitors?

_____ (%)

(c) Be held up and lose their production/business

_____ (%)

38 What proportion of your production/business lost in 1988 do you think was <u>taken up</u> later on by each of the following competitors?

Competitors within your town _____ (%)

Competitors within region* _____ (%)

Other competitors in country _____ (%)

Foreign firms _____ (%)

Not taken up by any competitors(permanently lost) _____ (%)

* Region = rest of greater district

39 In the event of any flood <u>now</u>, what proportion of your production/business loss do you think would be <u>taken up</u> by each of the following competitors ?

Competitors within your town _____ (%)

Competitors within region* _____ (%)

Other competitors in country _____ (%)

Foreign firms _____ (%)

Not expected to be taken up by any competitors(permanent loss) _____ (%)

40 Did the occurrence of floods in 1988 lead to <u>cancellation</u> of any foreign or local <u>contracts</u> for your business ?

Yes	1
No	2

41 If YES, what was the value of loss?

(i) Local _______ (Tk)

(ii) Foreign _______ (Tk)

42 Could you tell us what is the current level of capacity utilisation in your enterprise?

_____ (%) Now

_____ (%) Before flood

Transport

43 What are your normal modes of transport used in transporting your output to your customers?

	Yes	No	NA	% of use	NA
Roads	1	2	-8	_	-8
Railway	1	2	-8	_	-8
Boats	1	2	-8	_	-8
Ship	1	2	-8	_	-8
Air	1	2	-8	_	-8

44 What are your normal modes of transport in procuring your inputs?

	Yes	No	NA	% of use	NA
Roads	1	2	-8	_	-8
Railway	1	2	-8	_	-8
Boats	1	2	-8	_	-8
Ship	1	2	-8	_	-8
Air	1	2	-8	_	-8

45 If the roads used by you are submerged, can you manage your business through use of waterways?

Yes	1
No	2

46 If YES,
Compared to roads, to what extent are the use of boats

(a) In terms of money

	Yes	No	NA	Extent(%)	NA
More expensive	1	2	-8	_	-8
Cheaper	1	2	-8	_	-8
Same	1	2	-8	_	-8
Not sure	-	-	-	-	-9

(b) In terms of time/convenience

	Yes	No	NA	Extent(%)	NA
Disadvantag	1	2	-8	_	-8
Advantageous	1	2	-8	_	-8
Same	1	2	-8	_	-8
Not sure	-	-	-	-	-9

LINKAGES (To be administered only to industrial enterprises)

Forward linkage (Output)

47 List your main output showing proportion of total value.

Output	% of total value
____________________________	_________

48 To your knowledge, can you identify the end-use of your main product?
(Responses to this Q should be based on group interview,comprising entrepreneurs, managers, workers etc)

End-use	Yes	No	NA	Proportion(%)
Consumers	1	2	-8	__
Farmers	1	2	-8	__
Industry	1	2	-8	__
Exports	1	2	-8	__

49 Where do you normally and <u>largely</u> sell your output?
(Answer one, most appropriate)

Within this town	1
Within the region*	2
Within the country	3
Outside the country	4

('Region' is defined as greater district)

Backward linkage (Input)

50 List your main input (raw material) indicating proportion of total value of use.

Input	% of total use
____________________________	_________

51 To your knowledge, can you identify the origin of your main input?

Origin	Yes	No	Proportion(%)
Industries	1	2	__
Agricult.	1	2	__
Imports	1	2	__

52 Where do you normally and largely buy your inputs from?

From	
Within this town	1
Within the region	2
Within the country	3
Outside the country	4

53 If you could not purchase inputs from your customers during and after a flood, for what proportion would they

(a) be able to sell to your competitors? ______ (%)

(b) be held up and lose their production/business ______ (%)

54 Other than repair and replacement of the damages due to 1988 flood could you give us an account of your <u>investment</u> since 1988?

Items	Year	Invest(Tk)
Buy/replace machine	_	_____
Buy new building/land	_	_____
Increase premise	_	_____
Increase work capital	_	_____
Others	_	_____

55 Did you have to reduce your investments/facilities for some reason or the other during the same period since 1988?

Yes	1
No	2

If YES,

Items	Year	Amount(Tk)
Sell old machine	_	_____
Sell new machine	_	_____
Sell building/land	_	_____
Sell other assets	_	_____
Decrease premise	_	_____
Decrease work. capital	_	_____
Others	_	_____

56 Could you describe your reason behind the reduction of investment above,if any? (Record verbatim)

____

____

____

57 Compared to the time 6 months before 1988 flood, were the following same, less or more during 6 months after the flood (due specifically to flood effects)?
Give % of pre flood level: Pre flood level=100,(NA = -8)

(i) Income of the industry ________ (%)

(ii) Demand for output ________ (%)

(iii) Employment opportunities in industries _______ (%)

(iv) Industrial wage rates ________ (%)

(v) Price of industrial goods ________ (%)

WARNING

58 During the flood of 1988 were you <u>warned</u> of the possibility of flooding?

Yes	1
No	2

59 If YES,

(a) Were you <u>warned</u> about the possibility of flood by any of the following?

	Yes	No	
Water Development Board	1	2	
Ministry of Flood	1	2	
Chamber of Commerce	1	2	
Other gov't dept.	1	2	
Police	1	2	
Local authority	1	2	
Municipality	1	2	
District official	1	2	
UZ/Thana authority	1	2	
Red Cross	1	2	
Media(Radio/Television	1	2	
Others (specify)	1	2	__________

(b) How many <u>hours before</u> flood water entered your property were you warned?

Before _______ (hours)

(c) What was your reaction when you received the message of warning?

Believed the message	1
Didn't believe at all	2
Not certain	3
Don't know	4
NA	-8

<u>Perception</u> (Informal warning)

60 Irrespective of any official warning given, were you able to <u>perceive</u> that flooding was going to occur?

Yes	1
No	2

If YES,

61 How did you <u>become aware</u> of the possibility of flooding? (mention three most important sources)

Through

Reading news paper	1
Excessive rainfall	2
Flooding in neighbouring areas	3

Rising level of nearby rivers	4
Message from friends/relatives	5
Impression from elderly people	6
Migration of rats	7
Others (specify)...........	8

62 How many hrs before it happened, did you realise that the flooding was going to happen at your site?

hours _____

63 Do you have any idea of how many hours after the flood water entered into your town did it take to start entering into your own property?

hours _____

64 Could you manage to remove some of your goods/materials to a safer place by the time you received formal or informal warning?

Yes	1
No	2

65 If YES,

What proportion of the following materials were you able to remove to safer places?

Materials	% of value at risk	% of exposed items removed	Amount removed (TK)	Potential damages avoided(TK)
Stock of input				
Stock of output				
Machinery /equipment				
Others				
Total (to be calculated later)				

66 If some goods/materials were removed, where did you transfer these? (mention three important places)

Removed to:

Firms other sites	1
Own house in this locality	2
Own house in other locality	3
Neighbours of this locality	4
Friends of this locality	5
Friends of other locality	6
Relatives of this locality	7
Relatives of other locality	8
Public buildings/Relief camp	9
Not applicable	-8

67 Overall has flood threat altered the management of your business and how you operate from what it would be if there were no flood threat? (Record verbatim)

____

____

____

68 (Applicable: Q (a & b) for 1993 flash flood; Q (a, b, c & d) for 1991 tidal flood)

Now,finally,based on your experience of damages caused to you in the last flood of 1991/1993,could you segregate your total damages(in %)to each of the following items on account separately of Inundation,water Velocity,Storm and Salinity:

		% Damage to		
		B Structure	Machinery etc	Stock
(a)	Inundation alone (normal velocity)			
(b)	Water Velocity			
(c)	Stormy wind			
(d)	Salt contamination			

THANKS FOR ALL YOUR HELP AND COOPERATION

APPENDIX H: CHECK LIST: LAND USE, LAND LEVEL AND FLOOR HEIGHT SURVEY

1 SERIAL NUMBER

2 NAME OF MAIN ROAD

3 REDUCED LEVEL OF MAIN ROAD RELATING TO PWD BENCH MARK (TO ENTER LATER BY PHYSICAL MEASUREMENT)

4 GROUND LEVEL (GL) OF BRANCH ROAD RELATING TO MAIN ROAD (INCHES)

5 G L OF HOUSE/ENTERPRISE IN RELATION TO BRANCH ROADS (INCHES)

6 SECTOR CODE OF PROPERTY

7 CONSTRUCTION TYPE (FOR SECTOR 1 ONLY)

8 NAME OF SUB-SECTOR (FOR SECTORS 2/3/4)

SUB-SECTOR CODE FOR BUSINESS (TO ENTER LATER)

SUB-SECTOR CODE FOR INDUSTRIES (TO ENTER LATER)

SUB-SECTOR CODE FOR OFFICE (TO ENTER LATER)

9 FLOOR HEIGHT IN RELATION TO G L OF HOUSE/ENTERPRISE (INCHES)

10 GROUND SPACE (ONLY FOR SECTOR 4) IN SFT

SECTOR CODE

Residential	1
Business	2
Industries	3
Office	4

HOUSE CONSTRUCTION TYPE FOR SECTOR 1 (RESIDENTIAL SECTOR)

Brick(floor),Brick(wall)	-BB	1
Brick(floor),CI sheet(wall)	-BC	2
Mud(floor),CI sheet(wall)	-MC	3
Mud(floor),Thatched(wall)	-MT	4