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System Design for Periodic Data Production Management

A thesis submitted to School of Computing Science,
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in partial fulfilment of the requirements for the degree of Ph.D

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Abstract

This research project introduces a new type of information system, the *periodic data production management system*, and proposes several innovative system design concepts for this application area.

Periodic data production systems are common in the information industry for the production of information. These systems process large quantities of data in order to produce statistical reports in predefined intervals. The workflow of such a system is typically distributed world-wide and consists of several semi-computerized production steps which transform data packages. For example, market research companies apply these systems in order to sell marketing information over specified timelines.

There has been identified a lack of concepts for IT-aided management in this area. This thesis clearly defines the complex requirements of periodic data production *management* systems. It is shown that these systems can be defined as IT-support for planning, monitoring and controlling periodic data production processes. Their significant advantages are that information industry will be enabled to increase production performance, and to ease (and speed up) the identification of the production progress as well as the achievable optimisation potential in order to control rationalisation goals. In addition, this thesis provides solutions for the generic problem how to introduce such a management system on top of an unchangeable periodic data production system.

Two promising system designs for periodic data production management are derived, analysed and compared in order to gain knowledge about appropriate concepts and this application area. Production planning systems are the metaphor models used for the so-called *closely coupled approach*. The metaphor model for the *loosely coupled approach is* project management. The latter approach is prototyped as an application in the market research industry and used as case study. Evaluation results are real-world experiences which demonstrate the extraordinary efficiency of systems based on the loosely coupled approach. Special is a scenario-based evaluation that accurately demonstrates the many improvements achievable with this approach. Main results are that production planning and process quality can vitally be improved. Finally, among other propositions, it is suggested to concentrate future work on the development of product lines for periodic data production management systems in order to increase their reuse.

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List of abbreviation

BPM	Business process management
ERP	Enterprise resource planning
FIFO	First-in-first-out
GUI	Graphical user interface
IS	Information system
IT	Information technology
JEE	Job execution environment
JS	Job scheduling
KPI	Key performance indicator
MIS	Management information system
MRP	Manufacturing resource planning
PDP	Periodic data production
PDPM	Periodic data production management
PM	Project management
PPS	Production planning system
SFP	Shop floor planning
SPC	Statistical process control
TQM	Total quality management
WFM	Workflow management
WFMS	Workflow management system

Overview of published research papers

This overview shows published papers of the author, Anja Schanzenberger, relating to this research project. Please find the corresponding abstracts of the published papers in appendix F.

research papers	outcomes are used in section	responsible of paper
Anja Schanzenberger, Dave R. Lawrence, Thomas Kirsche: *Enhancing Project Management for Periodic Data Production Management,* Lecture Notes in Computer Science, Volume 3762/2005, OTM Workshops 2005 - CoopIS, Springer Verlag Heidelberg, p.9-11 Agia Napa, Cyprus, Oct. 2005	2.3.1, 5.2, 6.3.5, 7.5	the author is responsible for the whole paper.
Thomas Kirsche, Gerhard Baumann, Anja Schanzenberger: *Alignment of Product Master Data,* Informatik-PRODIS 2005: Workshop on Product-related Data in Information Systems, Lecture Notes in Informatics, Koellen Druck+Verlag GmbH, Bonn, p. 449-453 Bonn, Sept. 2005	1.2.1, 2.2.2, appendix B	the author is responsible for chapter 1, section 3.1 and chapter 4.
Anja Schanzenberger, Dave R. Lawrence: *Options for Periodic Data Production Management,* International Journal for Computer Systems Science & Engineering (2005) 3, CRL Publishing Ltd. London, p. 203-217 Mai 2005	1.2.2, 2.2.4, 2.3.2, 2.3.3, 3.2, 4.2, 5.2, 6.3, 7.5	the author is responsible for the whole paper.
Anja Schanzenberger, Dave R. Lawrence: *Automated Supervision of Data Production - Managing the Creation of Statistical Reports on Periodic Data,* Lecture Notes in Computer Science, Volume 3290/2004, OTM Confederated Int. Conferences - CoopIS, Springer Verlag Heidelberg, p.194-208 Agia Napa, Cyprus, Oct. 2004	1.2.1, 2.2.4, 3.2, 4.2, 5.2, 6.3, 7.5	the author is responsible for the whole paper.
Anja Schanzenberger, Dave R. Lawrence: *A Web Service Based Approach to Monitor and Control a Distributed Component Execution Environment,* Conference Euromedia-WEBTEC 2003 Proceedings, p. 69-76 Plymouth, UK, Apr. 2003	1.2.1, 2.2.2, appendix A	the author is responsible for the whole paper.
Anja Schanzenberger, Colin Tully, Dave R. Lawrence: *Ueberwachung von Aggregationszustaenden in verteilten komponentenbasierten Datenproduktionssystemen,* translation by A.S.: *Monitoring of Aggregation Levels in Distributed Component-Based Data Production Systems* BTW 2003: 10th Conference on Database Systems for Business, Technology and Web, Lecture Notes in Informatics, Koellen Druck+Verlag GmbH, Bonn, p.544-557 Leipzig, Feb. 2003	1.2.1, 1.2.2, 2.2.2, 2.2.4, 3.2, 4.2	the author is responsible for the whole paper.
Anja Schanzenberger, Wolfgang Lehner: *Einsatz von WebServices in daten-intensiven Umgebungen,* translation by A.S.: *Using Web Services in Data-Intensive Environments* Gesellschaft fuer Informatik FG 2.5.2, Workshop: Entwicklung von Anwendungen auf der Basis der XML Web-Service Technologie, Workshop Proceedings Darmstadt, July 2002	1.2.1, 1.2.2, 2.2.2, 2.2.4, 3.2, 4.2	the author is responsible for the whole paper except parts of section 3.

Table 0.1: Research papers, the related chapters and the authors responsibilities

Chapter 1

Introduction to periodic data production management and the research for related system design concepts

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Chapter objective

    This research project focuses on system design for periodic data production management, the IT-aided supervision of periodic data production. In this chapter periodic data production is introduced by presenting a real-world example from industry. In order to characterise the area of interest the problems with former periodic data production management are described using this example. These business problems are provided to motivate this research project.

    To clarify the scope of interest and the methodology used, a specification of the research project is outlined. Finally, to support navigation through this thesis, the thesis structure is explained.

Chapter contents

1 Introduction to periodic data production management and the research for related system design concepts

"Management Information System (abbr. MIS): An information system is used for storing, retrieval, assigning and reporting information. An information system consists of a database system, data models, classification of data and reporting programs. It is normally distributed on several computers or on several servers in a network within an organisation. ... A management information system stores all parameters and key figures which are necessary and useful for optimal leadership of an organisation ... Especially for decisions in industry, decision support systems are used."

(Duden – Informatik, 2001, 304-305, translation from the German original by AS)

1.1 Introduction

This research project deals with the periodic processing of time-related statistical data through several distributed production steps repeated in intervals, and especially with its IT-aided supervision.

As there is no commonly established term to describe this type of periodic data processing and its supervision this thesis has to introduce two new terms: It refers to this type of periodic data processing as *periodic data production* (PDP) and to its supervision as *periodic data production management* (PDPM). Only links for the more general term *data production* are to be found, but the concepts referenced, are not clearly defined. PDP is a more specialised activity and has its own characteristics and requirements. To investigate them, a detailed description is provided in this thesis (see section 2.2.2).

Albrecht et al. explain that, in building a data production system, immense volumes of periodically gathered data in one specific area are transformed into aggregated multifaceted information (Albrecht et al., 1997, 651-656). In defined intervals, this information is produced and presented in the form of statistical reports and graphics. The repetitive character of information production and presentation is useful to observe the developments of a specific area over a defined timeline. For example, meteorological tracking data, business market developments and statistical analyses for governments are areas to be periodically observed and analysed. The associated producer organisations, as for example market research companies, generate regularly statistical reports for their customers.

There is a connection between PDP and goods production. It is well known that traditional goods production can be divided into many different sub-categories to satisfy many sectors of this industry (Hahn, 1972; Hoitsch, 1993; Dangelmaier & Warnecke,

1997). As statistical data can be interpreted as non-physical goods, PDP can be understood as a type of goods production in a wider sense. This interpretation includes that traditional goods are substituted by digital information. More precisely, PDP is the appropriate method used in the information industry to produce the product *information* (cp. definition of the term information in (Flensburg, 2004, 182)).

Based on the experience in goods production that manufacturing requires support by adequate IT-aided management, sophisticated system design concepts for the special case of PDPM systems are investigated in this thesis. The aims of goods production management and PDP management coincide, namely to control timing, costs and resources, but the underlying systems differ as PDP systems are a mixture of traditional production systems and data processing systems. This significant difference has to be reflected.

PDPM systems are a type of management information systems (MIS). They are designed as decision support systems to assist management and operators by providing reliable information about their PDP processes, which in turn are supported by PDP systems. PDPM systems considerably contribute to business success in organisations where PDP systems are used (see section 2.2.4).

This thesis investigates concepts of PDPM and PDPM systems. It focuses on research into suitable system design concepts for IT-aided PDPM (see section 5.2). In addition to the introduction of this new system type the strength of this thesis is that appropriate concepts are compared, a promising approach is prototyped, and finally the prototyped concept is completely evaluated. The prototyped PDPM application which is presented in this thesis (see section 6.3) in order to include experiences from industry is used as a case-study and has been developed for a real-world company. This company is a leading organisation in the business of market research. Its recently implemented PDPM application is a qualified test bed for evaluating the concepts proposed in this thesis.

In the scope of this research project there are PDPM functionalities such as automating the planning and automating the monitoring in PDP (see section 1.3.1). A main purpose is to support time management by providing adequate key performance indicators and workflow overviews in order to achieve transparency in all PDP production cycles. This thesis demonstrates that a PDPM system is an extremely useful application in order to achieve sophisticated, IT-aided management which is indispensable for adequately controlling modern PDP systems. The presented research results enable interested stakeholders (system designers as well as strategic, tactical and operational management) to decide about which conceptual PDPM options are suitable in their PDP environments. In

addition, the results confirm the innovativeness of the introduced and prototyped concept by its specially effective design for IT-aided PDPM (see section 5.2.3), its simplicity of use in practice (see chapter 6) and its positive evaluation in industry (see section 7.6).

The intention of this chapter is to introduce PDPM (see section 1.2). Accordingly, the problem area of PDPM is presented by showing a real-world example. A description of this research project follows in section 1.3. Its scope and the aims are explained in detail. Its research issues are discussed and the methodologies used are introduced. The contribution of this research is highlighted. Finally, section 1.4 outlines the thesis structure.

1.2 The business problem of periodic data production management

The PDPM business problem is not explained using some simple examples because this would hide the complexity of the problem area. As a consequence it is explained using the larger example of a world-leading market research company in order to give an impression of PDP in the information industry. The company's PDP system is introduced in section 1.2.1. The description of its complex, previously non-automated, and problematic PDPM procedures follows in section 1.2.2. Accordingly, both sections exemplify the business problems of PDPM which are addressed in this research project.

1.2.1 Example of a periodic data production system in the information industry

The GfK Group is a leading market researcher. This company provides business information which contains the essential knowledge that their customers in industry, retail and service sectors need in order to make their marketing decisions. GfK Marketing Services (GfK MS, 2006), one of four main divisions of GfK Group, produces statistical reports from periodic observation of retailers world-wide (e.g. periodic reports concerning competition, demographic evaluation of subsidiaries or product 'hit'-lists).
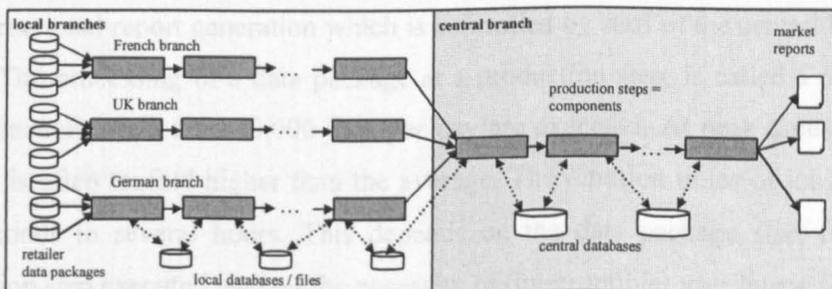
Figure 1.1: Simplified workflow of a distributed PDP system (Schanzenberger & Lawrence, 2004, 195)

The PDP system of GfK Marketing Services, called 'StarTrack' (i.e. System To Analyse and Report on Tracking data), was initially set up for Western Europe, but has now been extended to include the main New Democracies of Eastern Europe, Asia and the

Pacific Basin, as well as the American Continent. This world-wide operating PDP system is already available in more than 60 countries, and is based on centralised master data of markets, retail structures, product-groups, -models and -features. This PDP system is an excellent example for an object to be controlled (see section 2.2.2) by a PDPM system whose concepts will be investigated in this research (see section 2.2.4).

The data collection is distributed as shown in figure 1.1. Each country has a branch of the company where the periodic data is collected. Staff at the local branches of the PDP system is importing the data. Data import is done either by importing electronic media or by scanning and importing information from field research. Roughly 30,000 different data packages per month are gathered from an appropriate sample of retailers (ca. 10,000) in order to offer a high market coverage.

Around twenty sequenced production steps are necessary in each country's branch until the periodic data has been identified, unified, checked against the master data (cp. definition of the term master data in (Chrisholm, 2001, 3)) and sent to the central branch in Nuremberg, Germany. This process is centralised to establish an international reporting base. The workflow continues at the central branch and includes roughly forty additional production steps. These production steps include data processing, analysis, report preparation and distribution.

Tens of terabytes are processed at the data entrances in the country branches. These data volumes are reduced to around 750 GB each year that are used for production at the central branch. Approximately 5000 different report types per month are produced with the central reporting base.

Some of the production steps are fully automated, others offer possibilities for user interactions. The applications use web technology in order to guarantee world-wide access. The whole workflow is usually controlled by staff located in the country branches, except the international report generation which is controlled by staff of the central branch.

The processing of a data package at a production step, is called a production job. Approximately more than 20,000 jobs per day are executed. At peak times however, this number is often tenfold higher than the average. The duration times of jobs can last from few seconds to several hours. This depends on the data package size, on the type of production step executed, and on the necessity of (interruptible) user interaction.

Unfortunately, it is not an exception if thirty to fifty percent of the delivered data packages are delayed at the local entrances of the system or are replaced due to data quality reasons. Delayed deliveries are usually caused by the retailers which regularly provide their sales data. This can cause deviations in the time scheduling of the whole production

process. Deviations from the normal production plan can also be caused by replacing low-quality data packages. In this case, data packages from a retailer are replaced by data packages from another retailer or another delivery period, because a correct statistical end-report only depends on the correct sample and extrapolation formulae and not on any specific source data. However, both types of deviations (cp. section 2.2.2, point C.4) complicate PDP and PDPM. A more detailed description of this PDP system and its workflow can be found in appendix B.

1.2.2 Problems of former periodic data production management on the example

Fact is that the economic survival of a company depends on reliable and continuously available management information. PDPM systems based on the concepts introduced in this thesis deliver this information in PDP environments. Without such a tool support a lot of problems can be observed. The problem description provided in this section has been gained by examining the former PDPM procedures that were common at GfK Marketing Services prior to the implementation of the prototype application (see section 1.2.1). The problem description allows the identification of necessary improvements for PDPM which shall be achieved. It especially explains why research into appropriate computerised supervisory methods is substantially important.

<u>Description of the former PDPM procedures and identified problems</u>

A flood of diverse problems has been identified by investigating GfK's PDP system. Most of them are related to the decentralised workflow, to providing on-time deliveries to the next workflow segments, and to providing an improved overview of the non-transparent handling of the huge amount of data and its changes during the production process (see details in section 2.2; section 2.3). Accordingly, the PDPM concepts introduced in this thesis have to be able to improve and solve the following problems:

1. *Transparency problems* (see details in section 4.4, points 1,2): A production overview of the data flow was not available due to the lack of relationships between data packages. Tracking the data flow was only partially possible and not for the whole workflow. The lack of relationships hindered tracking the report sources because of the fact that product identifiers of the data packages change during their flow through the workflow (see description in section 2.2.2, point C.2). However, the correct identification of report sources was considered as necessary for improving the trustworthiness of the business information offered to customers.

2. *Problems with decentralised non-standardised PDPM procedures* (see details in

section 4.4, points 3,4): Each involved branch, department or working group had its own PDPM procedures. Some had a set of manual procedures, others had some in-house developed software tools. Management information was not available or has not satisfyingly been shared. National and particularly international production overviews could only be generated with high manual effort. Accordingly, a PDPM system has to standardise and automate management procedures. The main problems which a PDPM system has to tackle with can appropriately be categorised into planning, monitoring and controlling PDP (see section 2.3.3).

Planning:

- Result of the non standardised and non automated procedures: planning resources, costs and timing were based on uncertain information. Hence, production plans could not be verified without doubts.

- A comparison between planned and actual production was almost not practicable without adequate computerised support.

- Work lists for participants and/or capacity utilisation overviews were not available.

- Production jobs were served on a FIFO-base (urgent/important jobs not preferred).

- Work groups only planned the data packages on their own responsibilities.

- Waiting times in case of responsibility changes were unknown.

- Time management was difficult due to the differences between delivery periods, intermediate periods and reporting periods in this business. However, staff in each workflow segment is dependent on punctual production in the previous segments.

- Time management is crucial in PDP because the value of information is time sensitive (e.g. a report which includes old marketing information cannot be sold)

Monitoring:

- Specific information of the production jobs is visualised by logs on web pages. The permanent polling procedure should be improved by proactive notification.

- The level of job logs includes too many details. This level is not useful and suitable for appropriate production overviews as the sheer amount of log entries is usually overwhelming. Management needs condensed overviews.

- Job predecessor and successor relationships were not known in every case. That made it difficult to coordinate the timing between the working groups.

- No common process for collecting management information on an international base was established. Adequate management was difficult.

Controlling:

- Gathering PDPM information manually was uncertain, costly and time-consuming.

- Production costs have been shared on manual work load estimations.
- Staff responsible for collecting management information was distracted from the actual production itself, which could have caused production delays.
- The result was that management information was not produced on a regular base.
- Ad-hoc management reports were only presented to management when answers to questions were requested.
- The performance, the progress and the optimisation potential of production was unknown or could only be estimated.
- Standardised key performance indicators were not applied.

3. *Workflow-related problems* (see details in section 4.4, point 5): As this workflow is distributed, collecting management information was difficult. Several systems, logs of production steps and written information needed to be evaluated in this case. No centralised, standardised and internationalised management information system was available. As this workflow is also voluminous with its several stages and around sixty production steps and as many work groups with different working styles have been affected, this problem was not handled sufficiently.

The consequences

GfK Marketing Services concluded that continued business success can appropriately be guaranteed with automated PDPM based on a concept introduced in this thesis. It has been decided to implement a centralised PDPM system that standardises the management information for all participants.

Due to the lack of appropriate PDPM systems and their concepts, this research project has been set up. This section has shown, the many functionalities and the high complexity that a PDPM system has to incorporate must be reflected in adequate system design concepts. The generic problem how to introduce a management system on top of an unchangeable PDP system has to be addressed.

1.3 Specification of this research project

To carry out a research project successfully, a concise formulation of the research is necessary. The aim of this section is to explain this research project in detail.

In figure 1.2 is explained that this research project is in the area of PDPM research. It has a encircled scope which is described in section 1.3.1. The outlined scope considers the aspects which are investigated during this research project, and specifies others which are excluded. Relevant aims are selected for this research project and are explained in

section 1.3.2. Compatible research issues of interest have been chosen in section 1.3.3. The results of this research project create a contribution to the research community. A description how this research project contributes to additional understanding in the research community is provided in section 1.3.4. Appropriate methodologies have been used to reach the aims and objectives of this research project. Section 1.3.5 informs about the research methodology for a clearer understanding as to how this research was performed.
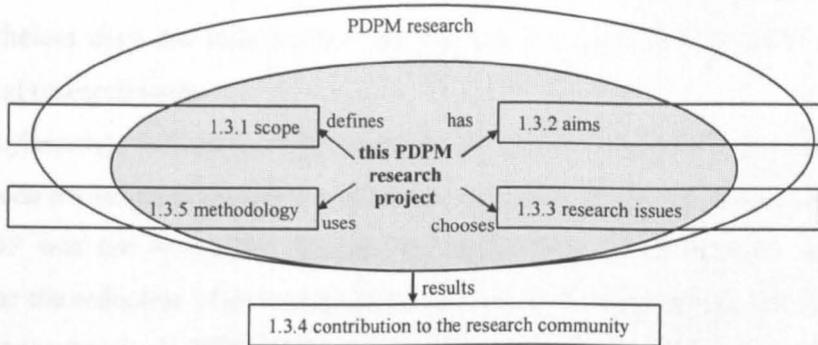
Figure 1.2: Specification of this research project

1.3.1 Scope

The purpose of this section is to summarize the scope of this research project and to clearly define which functions are considered and which are excluded, so as to limit the research to the most relevant features (see table 1.1). The following decisions determine the inclusion or exclusion of functionality. Furthermore, the numbering in table 1.1 is used to correlate the aims presented later in section 1.3.2 and the research issues described in section 1.3.3 to the scope of the research project.

no.	in scope	out of scope
S1	automating the planning and monitoring	automated controlling
S2	providing time management	cost and resource management
S3	providing most relevant key performance indicators	complete performance measurement
S4a	workflow overview	workflow definition
S4b	sketching job execution, error detection and system health information	complete discussion of job execution, error prevention and conserving system health techniques
S4c	process quality and transparency of the production process	data quality issues
S5a	theoretical discussion of system design alternatives for PDPM	testing of all system design alternatives
S5b	theoretical discussion of off-the-shelf products	complete testing all combinations of off-the-shelf products
S6	partial implementation of a prototype for PDPM (time management) in a real-world company	complete implementation of multiple prototypes
S7	Creating system design concepts and their evaluation	User-related issues and their evaluation

Table 1.1: Overview of the scope of this research project

S1. *Planning and monitoring:* As investigated in section 2.2.4, planning, monitoring and controlling for PDPM requires high automation, because operators should have the chance to concentrate on production itself and to be relieved of production

administration. Models for this form of automation can be described as system design concepts. In order to focus on the most basic aspects (i.e. planning and monitoring) in this research project, automated controlling is excluded. This aspect needs the both other aspects as pre-condition and can easily be complemented after automated planning and monitoring has sufficiently been installed.

S2. *Time management:* Time management in PDP is the main aspect addressed in this thesis. However, cost and resource management are not considered in detail. Nevertheless they are also highly relevant but not discussed in order to limit the practical research work.

S3. *Key performance indicators:* The most relevant key performance indicators for PDPM have been investigated during this research, but a complete performance measurement for PDP was not envisaged. A complete performance measurement process might examine the reduction of processing times included in the programs of the production steps. Any changes in PDP itself are consequently excluded, since those activities can be seen as manually controlled activities.

S4. *Reliable job execution and process transparency:*

a. This research is not concerned with changing workflow definitions. Such changes may be manually handled consequences discovered from applied PDPM and are for example arranged by tactical management.

b. The reliable execution of the jobs in the workflow is of interest in PDP. In the proposed system design concepts described in chapter 5, job execution of PDP processes is outlined as PDPM is, in the broadest sense, also involved with reliable job handling (Leymann & Roller, 2000, 97 et sqq.). Reliable job handling is also concerned with prevention and detection of production errors. This research roughly outlines possibilities for production error handling, as early error detection can prevent delays in production (Klein & Bar-Yam, 2001). The complete investigation of it is excluded in order not to distract from time management.

c. Reliable job execution contributes to improve the process quality. Included in this research is the examination of process quality and transparency of the production process, but it is not concerned with enhancing data quality itself. Further research for advancing data quality can be found in (Wang et al., 2002; Hinrichs, 2002).

S5. *System design alternatives for PDPM systems:*

a. Possible system design concepts are compared and theoretically evaluated, including diagrams for production overview.

b. All system parts have been examined whether off-the-shelf software or academic

standards or established research results from literature can be deployed. If so, the expenditure and the development costs of a PDPM system could be minimized.

S6. *Prototyping:* For gaining results for this investigation, a practical part of this research is to create a prototype of one of the possible options for PDPM. This is implemented and evaluated at a world-wide distributed PDP system in industry to verify research results in practice.

S7. *Evaluation:* User-related issues are excluded from the scope as this research is about designing PDPM system concepts. Consequently, instead of evaluating user-related issues and the prototyped system in use it has been decided to focus on evaluating the effectiveness of the designed PDPM system concepts.

1.3.2 Research aims

Unfortunately, there is no 'state of the art' system designed especially for PDPM. Thus, this research project will attempt to identify similar approaches in comparable research areas in order to adopt / adjust established functions for PDPM or at least to learn from other but similar areas which features in PDPM are useful. This attempt leads at last to discover new potential system design concepts. The relevant aims of this research project are summarised in this section and non-functional business-related system requirements are sketched. The aims and the system requirements are correlated in table 1.2 to the research scope presented in section 1.3.1.

aims	scope
A1: finding and/or designing potential PDPM systems and theoretically discussing them	S1: automating the planning and monitoring S2: providing time management
A2: increasing process transparency in PDP	S4: reliable job execution and process transparency
A3: identifying advantages and disadvantages of PDPM system design concepts	S5: examining and comparing system design concepts
A4: implementation of a potential PDPM system prototype	S6: proving the research results by prototyping
A5: gathering experience in this area	S6: proving the research results by prototyping S7: evaluating the designed system concepts
business-related system requirements	scope
R1: automated process measuring	S1: automating the planning and monitoring
R2: advancing the time management	S2: providing time management
R3: comparing the production plan to the actual production	S3: providing most relevant key performance indicators
R4: provide decision support for management	S3: providing most relevant key performance indicators
R5: identifying optimisation potential	S3: providing most relevant key performance indicators
R6: increasing the automation of PDPM	S4: reliable job execution and process transparency

Table 1.2: Aims and business-related system requirements of this research project related to the research scope

The aims of this research are:

A1: to find and/or design potential PDPM systems for planning and monitoring PDP and to theoretically discuss them

A2: to increase the transparency of the PDP production processes

A3: to compare the discovered PDPM system design concepts for identifying advantages and disadvantages

A4:   implementation of a potential PDPM system prototype
A5:   to gather additional experience in this area

The achievement of these aims will lead to providing decision support for desired implementations of PDPM systems.

The non-functional business-related system requirements which are considered in this research project are:

R1:   automated *measuring* of processes instead of manual control samples: monitoring PDP
R2:   advancing the time management in the PDP process. To automatically obtain a production plan. IT-aided production planning instead of manual agreements (overlooking the chaos): production planning
R3:   to have the possibility to compare the production plan to the actual production
R4:   to provide decision support for management in form of key performance indicators
R5:   to identify and offer optimisation potentials in production for reaching a rationalisation effect
R6:   to increase automation in PDPM is important for ensuring rapid production, improving error prevention, increasing the reliability of management information, and achieving independence from staff's expert knowledge

1.3.3   The research issues

The following research issues have been recognized as being of particular interest in this research area and form the cornerstone of discussions in this thesis (see section 4.5; section 8.2). In table 1.3 the research issues are correlated to the research scope presented in section 1.3.1. This is to demonstrate the correlations in this research project.

research issues	scope
I1: identifying requirements and properties of PDPM	S1: automating the planning and monitoring S2: providing time management S3: providing most relevant key performance indicators S4: reliable job execution and process transparency
I2: identifying system design alternatives for PDPM and identifying in which scenarios they are useful	S5: examining and comparing system design concepts for PDPM
I3: investigating how new system design concepts for PDPM can be evaluated and identifying evaluation criteria	S5: examining and comparing system design concepts for PDPM
I4: identifying if prototyping is a viable approach for testing and evaluation	S6: proving the research results by prototyping

Table 1.3: Research issues of this research project related to the research scope

I1: What are the requirements for PDPM and what properties are critically important for a successful PDPM?
I2: What possible system design alternatives are there for satisfying the identified critical PDPM properties and are the various strategies particularly relevant for specific scenarios?
I3: How can new system design concepts for PDPM best be evaluated, in practical terms, and what are the most effective criteria for evaluation?
I4: To what extent is prototyping all or part of proposed new system design concepts and tools a viable approach to testing and evaluation?

1.3.4 Contribution

A main achievement of this research will be to provide decision support for desired implementations of possible applications in the area of PDPM and their systems. This section summarises how this research project will contribute to achieve this objective goal.

Requirements and system design alternatives: Today, there are no dedicated (but in industry urgently required) system design concepts in existence specialising in PDPM. Due to the fact that PDPM is similar to traditional production planning and also to process management for data processing systems, the aim of this research as shown in more detail in table 1.2, is to bring together production planning and process management into approaches for the IT-aided supervision of PDP, and to investigate possible methods for this synthesis. The requirements for establishing such a PDPM will be acquired during this research project, because they are not obvious or previously defined.

Comparison, discussion and test of system design alternatives: As the PDP industry is multifaceted, it will be especially beneficial to discuss not only one system design concept but to examine different alternatives. Additional to the identification process of the different system parts and tasks a system design concept for PDPM comprises, a comparison of available and proposed system design concepts and especially a fundamental evaluation of these alternatives will contribute essential knowledge for underpinning crucial and tenable recommendations. Furthermore to test the system design concepts and recommendations in practice a prototype will be implemented for proofing the results in a real-world PDP.

Decision support: This disciplined procedure will particularly advance the basis for decision support in this area. Consequently, this research will not only contribute theoretical insights, but also provide substantial experience in practice. This work will facilitate the interaction of professionals, researchers and academics as a result of better understanding the PDPM processes and their relevant and serviceable concepts.

Publications: The outcome of this research has been published since the beginning of this research project and the resulting research papers are listed in the preface (cp. table 0.1) in order to highlight in which sections of this thesis the results are described (see abstracts of published papers in appendix F).

1.3.5 Research methodology

To successfully carry out this research for PDPM systems, it is vital to choose appropriate research methodologies, as not every methodology is suitable in this case. In

this project, methodologies are applied which belong to the class of action research. The forms of action research exercised are designing system concepts, prototyping, and subsequently evaluation. In this section it is outlined why these methodologies have been chosen and why they are beneficial for this research.

Typological classification of this research project

Suitable research methodologies can be found in the area of design-science research (Järvinen, 2004, 10) which is also called constructive research (Järvinen, 2001, 88). Although the categorisation of methodologies proposed in figure 1.3 can be controversially discussed (e.g. adopting ethnography or grounded theory into action research and vice versa might be possible), Järvinen argues that methodologies of design-science research stress the utility of innovations (Järvinen, 2004, 10). Innovation building approaches and evaluation approaches are useful in case of this research project as system design concepts are discussed. Accordingly, action research is a methodology which suits to this research.
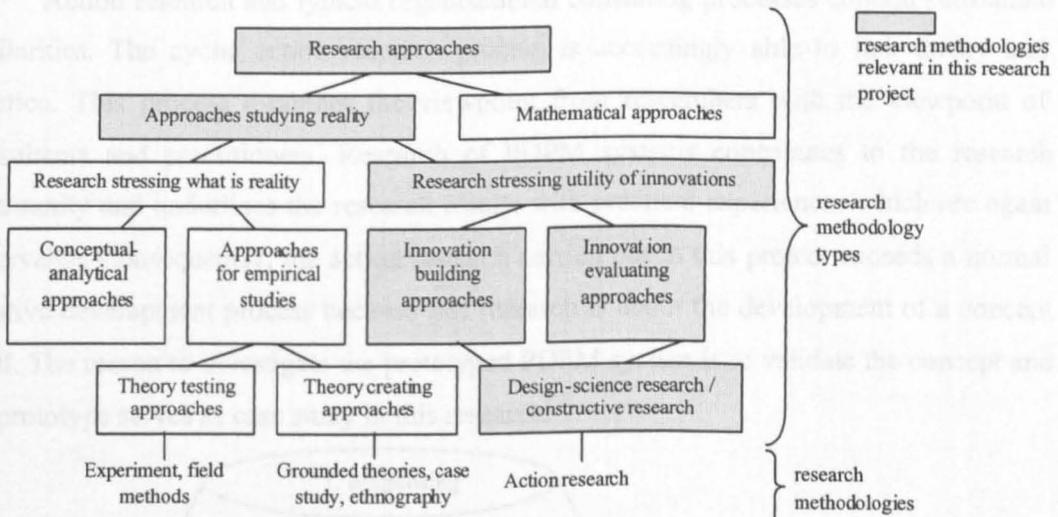
Figure 1.3: Taxonomy of research methodologies (adapted from Järvinen, 2004, 10)

Neither are conceptual-analytical methodologies nor are approaches for empirical studies the focus of this research project. For example, ethnography (Järvinen, 2004, 87-94) and grounded theory (Glaser& Strauss, 1998), do both extract data that can answer some parts of the chosen research issues. However, such methodologies do not suit completely this investigation because those methodologies can principally be used here for showing trends which PDPM strategies are currently preferred in industry, but do not lead sufficiently to research results for innovative new or alternative system design concepts.

However, for preparation of this research project ethnography in the sense of applying participant observations, PDP process observations, and face-to-face user interviews is used in order to understand the business processes and their related problems in industry. This preparation work is a pre-condition, because the understanding of the

subject area enables action research in this research project. Although this preparation work is not systematically documented and not discussed in this thesis, it is mentioned in this section for a better understanding of this project. Only the preparation work results are described and used in order to explain the input to the action research.

Overview of the procedure

The following list provides an overview of the procedure steps which are used in this research project:

- Conceptual work is to propose alternative system design concepts for automating and improving the manual procedures.
- An implemented prototype of such a PDPM system based on a proposed system design concept is used as case study and for the evaluation of this research project.
- The concept of the prototyped system is qualitatively evaluated by using a scenario-based evaluation approach and by analysing expert assessment questionnaires.

The chosen main methodology: Action research

Action research and typical organisational consulting processes contain substantial similarities. The cyclic action research process is accordingly able to link theory and practice. This process combines the viewpoint from researchers with the viewpoint of consultants and practitioners. Research of PDPM systems contributes to the research community and underlines the research results with practical experiences which are again observable. Consequently, the action research carried out in this project exceeds a normal iterative development process because this research is about the development of a concept itself. The reason to investigate the prototyped PDPM system is to validate the concept and the prototype serves as case study in this research.
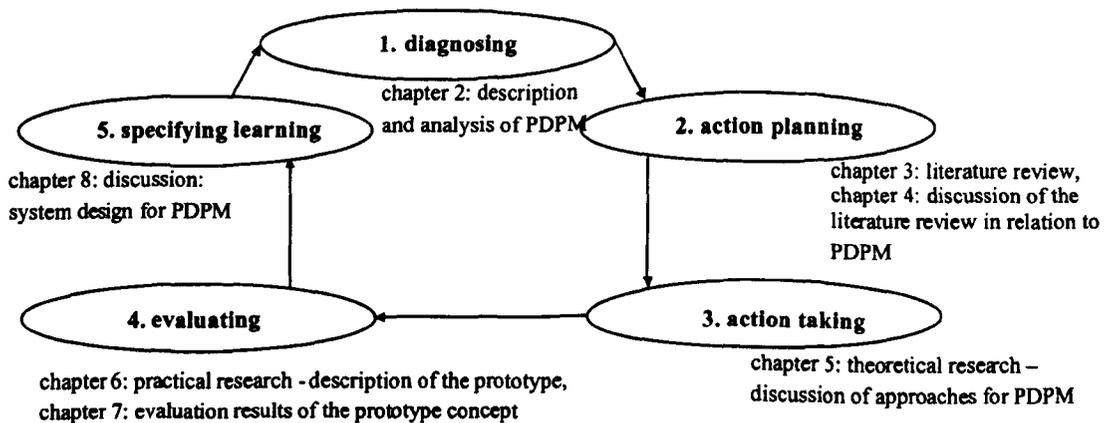
Figure 1.4: The action research methodology used for this research project

Action research applied in this research project

Baskerville summarises that action research is particularly effective for studying how human organisations interact with information systems (Baskerville, 1999, 1-23). This

is a further reason why in this thesis action research is adopted for the investigation of the PDPM concepts. This methodology implies that researchers and practitioners collaborate to bring the project to success. The win-win situation by using action research in this project is that the researcher can contribute system design concepts to the research community, and that the practitioners obtain solutions, as for example real-world information systems, that are based on these frameworks. Susman and Evered describe action research as an iterative process of five phases (Susman & Evered, 1978, 582-603; cp. Baskerville, 1999, 9-10; cp. Järvinen, 2004, 125-126). These five phases depicted in figure 1.4 and are explained as follows:

1. *Diagnosing: Describing PDPM* (see chapter 2):

Baskerville discusses that diagnosing is the process to identify the primary problems that are the causes of the organisations' desire for change (Baskerville, 1999, 10). A diagnosis of PDPM and the identification of its need in industry is described by attempting a comparison of traditional goods production management and PDPM. Accordingly, goods production is used as metaphor for PDPM. The investigation of its differences lead to the detailed discussion of appropriate PDPM system design concepts in this thesis. The result of the diagnosis is that a PDPM system is a complex mixture of a traditional goods production management system and a data processing management system and that this mixture needs further investigation. These results are confirmed by investigating the former manual PDPM procedures in industry which are described in section 1.2.2. As the requirements of PDPM are not described in detail in literature, a detailed analysis of PDPM is necessary. This analysis is described in section 2.3. The requirements are derived by observing a real-world PDP system in industry, but can be used and extended for PDPM systems in general.

2. *Action planning: Studying metaphor models for planning new system* design concepts (see chapter 3; chapter 4):

The actions that are necessary for improving the situations which are caused by the identified primary problems, are planned in this phase of the research. In this research project the result of the detailed literature review is that no specific PDPM systems are available regardless of academic or commercial solution. Although similar systems from the areas of traditional goods production management and data processing management do not deliver appropriate systems, they can be used as metaphors for finding suitable PDPM system design concepts. The discussion of available approaches described in literature results therefore in the specific description of present problems identified in PDPM

systems (see section 4.4). The actions that are planned are to reduce the identified remaining problems by introducing new system design concepts for PDPM which are based on established metaphors.

3. *Action taking: Designing PDPM systems* (see chapter 5):

From an academic point of view designing systems is the preferred method in this research. Several system design concepts for PDPM are proposed and serve as a discussion base in this application area.

For the intended purpose methodologies are demanded where potential alternative concepts are allowed. The added value with such methodologies will only be fully apparent when potential alternatives are then compared, recommended for different environments, and tested to gather experiences about advantages and disadvantages in practice.

In such complex systems like PDPM systems, more than one system design concept is suitable. An appropriate approach to describe the complexity of a system is to design a model. As with all modelling techniques, system design concepts are not provable beyond doubt. This is why it is beneficial in this research to conceive complementary design concepts. In addition, if companies select a system design they want to satisfy their requirements and they will always have preferences which can be easier satisfied if different options exist. Two candidate approaches have been designed and are presented in this thesis. In both cases their concepts are based on established applications which are used as metaphors. This means, one proposed approach is based on features which are commonly used in production planning systems, and the other is based on features well-known in project management. The advantage is the proposed approaches apply proven features and can be easily understood as the metaphors are well-known. These features are only adjusted were necessary in order to meet the special requirements for PDPM. Both approaches are compared. Both approaches discuss how the PDPM system can control the PDP system without introducing changes in the latter system.

4. *Evaluating: Prototyping and concept evaluation* (see chapter 6; chapter 7):

> "An evaluation is an assessment, as systematic and impartial as possible, of an activity, project, programme, strategy, policy, topic, theme, sector, operational area, institutional performance, etc. It focuses on expected and achieved accomplishments, examining the results chain, processes, contextual factors and causality, in order to understand achievements or the lack thereof."
>
> (United Nations Evaluation Group, 2005, 4)

After the generation of possible system design concepts there is a need to choose between methodologies for practical research as the proposed concepts have to be verified.

Discussed are the approaches of simulation and prototyping (Lantz, 1986, 1-3). However, the reason against using simulation is the opportunity to implement one of the proposed system design concepts for PDPM in a company with a real-world PDP system. This means for this research a PDPM system is not simulated in a laboratory, but major parts of a PDPM system are implemented in industry. This implemented PDPM system is the so-called *prototype* that has been created for GfK Marketing Services (GfK MS, 2006), which is a leading market research company.

Prototyping is an established research methodology (Lantz, 1986) used here for modelling, implementing, testing and installing an information system and its background functions for PDPM. Since PDPs can be comparably voluminous as factories (see section 1.2.1), prototyping a PDPM system is useful and appropriate in this project. Its iterative procedure allows to enlarge the new system step by step and to detect and avoid dead-ends early. The prototype is respectively a part of the evaluation process of this research project. Implementing one prototyped PDPM system in concern of this research was practicable.

Instead of auditing the prototype with a common cost-benefit analysis, its system design is evaluated to discuss the value of the concept. For this purpose the scenario-based evaluation methodology of information systems proposed from Schaik is applied and adapted (Schaik, 1999, 455-466). This methodology includes the discussion of scenarios which are achievable by using a system design concept. The analysis of expert assessment questionnaires (i.e. filled out by main stakeholders of the prototype) in relation to the scenarios contributes results which can be weighted and highlighted. These results are the weighted tangible and intangible benefits which are achievable when implementing a system design concept.

5. *Specifying Learning: Discussing research issues and main findings* (see chapter 8):
Learning from the presented research results and applying the outcomes for improving computerised PDPM in companies is usually an ongoing process. The outcomes provide knowledge for the research community to deal with future research settings in the application area of PDPM systems. Research issues and the main findings of this research project are therefore discussed. Possible future work is suggested and points to future cycles of research in this area.

Conclusion

In this research project action research is the chosen main research methodology. One cycle of the action research phases is completed. Data collection is carried out by gathering the observation results from a prototyped PDPM system, and by gathering data

from expert assessment questionnaires. The analysis of this research is achieved by using a scenario-based evaluation methodology which is particularly suitable in the area of information systems. This evaluation methodology includes the discussion of scenarios which are achievable by using a system design concept and investigating its achievable tangible and intangible benefits.

1.4 Outline of thesis structure

The aim of this section is to support adequate navigation through this thesis by outlining the thesis structure. A diagram of the thesis organization is depicted in figure 1.5.

A detailed description of PDP and PDPM is provided in chapter 2 by using goods production as a similar metaphor model. Additionally, an analysis of PDPM requirements follows in order to enable the search for suitable systems. In chapter 3 a literature review is provided. This chapter describes the ideas of other researchers in different related areas how to carry out production management. Research areas of interest and their related approaches within information system practice are identified. In chapter 4 the literature review and its connections to PDPM are critically discussed. The theoretical research of suitable system design concepts for PDPM is described in chapter 5. Relevant candidate approaches that have been designed during this research project are explained in detail. Traditional approaches provided in the literature review in chapter 3 are used as metaphors for these new approaches. A detailed description of the prototype created during this research project is provided in chapter 6. Reasons are discussed for choosing one of the candidate approaches. The detailed concept of this prototype includes the description of both, the user interfaces and background procedures. Dead ends and rejected aspects experienced during prototyping are outlined. Chapter 7 contains the detailed evaluation of the prototype's system design concept. Scenarios which considerably improve PDPM are described and highlight the effectiveness of this concept. Expert assessment questionnaires are provided for demonstrating the relevance of the achievable benefits. This enables a discussion about advantages and disadvantages of the proposed system design approach In chapter 8 a discussion of all relevant investigated concepts and their results is provided. The research issues are discussed in the review of the achieved results and the main results are summarised. The contribution for the research community achieved with this thesis is reviewed. Finally, possible future work in this area is discussed.

chapter 8 thesis discussion	discussion of research issues	summary and discussion of the thesis	prospect to future work summarisation (resume), main conclusions, contribution to research community				
chapter 7 result evaluation	identification of evaluation criteria	discussion of improved scenarios to present financial and functional benefits	analysis of expert assessment questionnaires	concept evaluation implemented approach (loosely coupled)	weighting and summarising intangible and tangible benefits		
chapter 6 prototype description	description of the prototype (IT independent)	IT concept & implementation	dead ends, rejected aspects (technical not historical order)				
chapter 5 approaches for PDPM	two proposed main candidate approaches & comparison & evaluation		closely coupled approach	loosely coupled approach			
chapter 4 discussion of the literature review	evaluation in relation to PDPM	PPS (production planning systems)	scheduling systems	WFM systems (workflow mgmt. systems)	exception reporting	monitoring systems	multi agent systems	traditional project management	combined approaches
chapter 3 literature review	identifying areas of interest and metaphor applications	PPS (production planning systems)	scheduling systems	WFM systems (workflow mgmt. systems)	exception reporting	monitoring systems	multi agent systems	traditional project management	combined approaches
chapter 2 description & analysis	Comparison of goods production and PDP and of goods production management and PDPM	General facts of PDP concepts and systems, industry independent, detailed definition; General facts of PDPM concepts and systems, industry independent, detailed definition;					
chapter 1 introduction order of doctorial thesis	Example of a PDP system and related PDPM problems	research issues & research aims	overview methodology	scope of research and excluded aspects	prototype for GfK marketing services		
	WHAT	WHY	HOW	SCOPE	WHERE		

Figure 1.5: Graphical chapter overview

20

1.5 Chapter summary

In this chapter a brief description of the business problem is provided and accordingly the need for IT-aided PDPM systems in industry is motivated (see section 1.2). It is introduced by sketching an example from the information industry. Structure and size of a world-wide distributed PDP system are shown to provide an impression of these large scale data factories. PDPM has previously been a manual task. PDPM systems are required for IT-aided planning, monitoring and controlling PDP. A PDPM system consequently observes all events which happen in the PDP system and offers decision support for production operators and management in order to identify optimisation potentials in PDP.

After description of the area of interest, the second part of this chapter concentrates on a specification of this research project (see section 1.3). The scope of the research reduces the focus on time management rather than on costs and resource aspects. For this reason, initially, planning and monitoring approaches are emphasized. The scope of this research is not related to data quality issues itself, but to provide a transparent production process and in consequence process quality. Concept description and evaluation is of interest instead of user-related issues.

Aims of this research are outlined and comprise the research for different system design alternatives which are theoretically compared and evaluated. The research issues of interest relate to questions for finding different options for PDPM. One of these options has been prototyped and developed during this research project in a real-world PDP to add experience in this area.

Finally, action research is the chosen main research methodology. Summarised, in the case of this research project, system design, prototyping, and scenario-based evaluation techniques are the main approaches applied for successfully conducting research.

Chapter 2

Description and analysis of periodic data production management

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Chapter objective

> The urgent need in industry for IT-aided systems and the identified problems discussed, have led to a conceptual discussion of periodic data production management. The paucity of sophisticated descriptions in literature are reason enough for further creative examinations. Consequently, a description of periodic data production management has been developed during this project and is revealed in this chapter by using goods production management as a metaphor. An analysis of essential PDPM system features complements the description. This chapter develops the requirements for sophisticated periodic data production management and explores its challenges and business goals. The most important cornerstones are discovered and investigated. Key performance indicators are proposed and can be used to subsequently express the development of production.

Chapter contents

2.1   Introduction
2.2   Motivation for research into periodic data production management
   2.2.1   Goods production used as metaphor for periodic data production
   2.2.2   Periodic data production
   2.2.3   Goods production management used as metaphor for periodic data production management
   2.2.4   Periodic data production management
2.3   Analysis of periodic data production management
   2.3.1   Functional requirements
   2.3.2   Challenges and business goals
   2.3.3   The cornerstones
   2.3.4   The most relevant key performance indicators
2.4   Chapter summary

2 Description and analysis of periodic data production management

2.1 Introduction

A pre-condition for adequate system design is to understand the system which is expected to be designed up to its very details. Amongst others, this includes the understanding of its requirements, components, and interfaces. This chapter is to develop such a deep understanding for PDPM systems in order to provide a common basis for the concept development.

In this chapter a detailed description of PDPM and PDPM systems follows in section 2.2. PDP and PDPM are described by using goods production and goods production management as metaphors. The analysis of fundamentally important functions and incidents within PDPM systems is presented in section 2.3.

2.2 Motivation for research into periodic data production management

This section motivates the discussion about PDPM systems by describing the non-unique use of the term *data production*. Understanding the nature of PDP will inevitably lead to more knowledge about PDPM.

Amongst the most important characteristics of PDP systems are the following. Usually, a PDP system is profitable when it has features such as:

- large amounts of data are processed
- data are similar structured
- tracking similar data content of a specific area
- similar and complex periodically repeated transformations over time
- many periods to be processed
- a high degree of repetition
- several production jobs run parallel
- usually world-wide distributed

The term *data production* is often mentioned with regard to data transmission processes of smaller quantities than the methods used in PDP indicated in reality. Those approaches often lack elements such as:

- the periodic gathering process of data from different sources
- the partitioning into different production steps
- or the periodic transformation of data into reports

Only IT systems possessing all the characteristics mentioned in section 2.2.2 are authentic PDP systems and only these deserve the name PDP.

As the descriptions of PDP and PDPM provided so far are only for a rough overview and are not sufficient more sophisticated descriptions need to follow. A goods production system is a useful metaphor when blueprinting a PDP system as similarities and differences help to understand the concepts of PDP in more detail. Accordingly, goods production and PDP are compared in section 2.2.1 and section 2.2.2.

IT-aided PDPM is the approach to automatically observe PDP systems. Its aim is to find optimisation potentials in relation of timing, costs and resources and to gain rationalisation (i.e. increase in production efficiency) where possible. Due to the similarities of goods production and PDP, goods production management systems are used as metaphor for explaining the essential elements of PDPM systems. Correspondingly, both system types are compared in section 2.2.3 and section 2.3.4.

2.2.1 Goods production used as metaphor for periodic data production

Goods production is a more traditional form of production in relation to PDP. It is well known and thoroughly studied in various researches. In order to use it as metaphor for PDP an overview of goods production consequently follows.

A. The most important basic concepts of goods production

Preparatory work in goods production is to plan a product. To produce it, materials need to be procured. Material planning requires arrangements for stock-keeping and defining lot-sizes. For enabling the transfer from material into products it is necessary to establish a production process, also referred to as production chain or workflow (Leymann & Roller, 2000, 7-12), and to describe the product. A distinctive feature is that the product can usually be described using a parts-list. This means, the source of each product part can be identified by referring to the parts-lists.

After ordering, the product parts are transported through the production chain. Usually, on assembly lines, the product parts move through various assembly processes. Assembly processes are also named production steps and can for example be milling, hammering, welding etc. Assembling the products occurs during processing time. Planning at this production stage requires, that all items are delivered in the right time to the right place.

One important feature used later for a more detailed description of PDP in section 2.2.2 is to differentiate between isolatable and non-isolatable intermediate parts in goods production. For example, conventionally isolatable parts are used in the automotive industry. A screw in a car can always be removed and is thus isolatable. The extent to

which this is important is demonstrated by an example, where the weight of a car can potentially reveal whether a single screw is missing.

An example for processing non-isolatable intermediate parts is found in the chemical industry. The producer and quality certification of *parts* can always be identified, but if liquids for example, are mixed together, they cannot always be separated afterwards.

B.   Outline of goods production
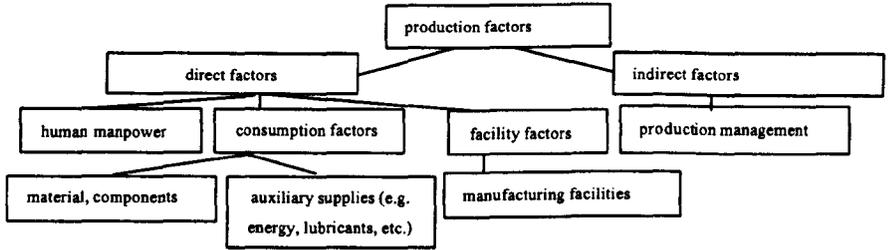
Figure 2.1: Production factors of production systems (Heinkel 2000, 7-9)

In definitive books about production management is discussed that due to the extreme variety in goods production there are many different academic definitions and typology models (e.g. Hahn, 1972; Hoitsch, 1993; Dangelmaier & Warnecke, 1997). One concise characterisation, we use later in section 2.2.2 for a description of PDP, can be found in the work of Heinkel (Heinkel, 2000, 7-9). Adopted from Heinkel, goods production is used for the operational construction of goods or services. Biz/ed describes the production factors of goods production as "the resources that are necessary for production. They are usually classified into the four different groups" land, labour, capital and enterprise. "The rate of economic growth that an economy can manage will be affected by the quantity and the quality of the factors of production they have." (Biz/ed Glossary, 2006). Heinkel divides the production factors into direct and indirect factors (see figure 2.1) (Heinkel, 2000, 7-9). All tasks for planning and controlling production are part of the indirect factors. Manpower, consumption factors and facilities are the direct factors of a production system. Consumption factors are transformed into products. For this transformation a goods production requires workers and manufacturing facilities.

2.2.2   Periodic data production

PDP is the main object of interest which must be observed by PDPM. Thus, a description of the most important features of PDP and its systems follows. As PDP shares the basic concepts coherent with its metaphor model *goods production*, this description can be created by comparing both concepts and outlining the differences.

A.   The most important basic concepts of PDP

Information industry uses PDP to produce the product *information*, for example in form of tabular statistics or business graphics (cp. section 1.2.1; appendix B). The end-product of PDP is correspondingly a statistical report. Preparatory work in PDP is to design and plan a report. To produce a report, data needs to be procured, as the material used for producing reports is basically data. Material planning requires arrangements for server storage and defining lot-sizes. In particular, lot-sizes are planned with respect to the fact that the end-product can be duplicated and be sold multiple times without more material consumption. For transforming data material into reports, a production process (i.e. production chain, workflow) must be established and the end-reports must be defined. Report description is usually the result of a requirement and design study, defining representative samples of source data and determining extrapolation formulas.

During run-time the source and intermediate data is transferred in a specific sequence from one production step to the next production step. The production steps which process the data material can, for example, include aggregating, separating or duplicating data (cp. point C.1). Planning during run-time requires that all items are delivered in the right time to the right place.

The sub-type of *data production* investigated in this research project is **periodic** **data production**. It can be defined as a repeated data production in intervals (among others important for producing statistics with timelines). This is important as PDPM and especially production planning can take advantage of the characteristics of PDP. The repetitive nature of PDP is correspondingly important when discussing the possibilities to automate PDPM and the possibilities to predict future production cycles (e.g. discussion in section 5.2.4, point B1; section 6.3.5).

B.   Outline of PDP
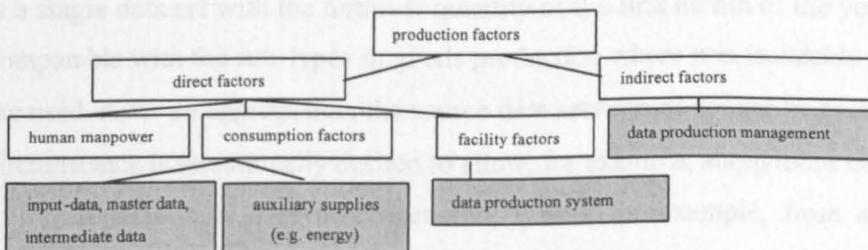
Figure 2.2: Production factors in PDP systems

To portray PDP more formally, the definition of goods production pertaining to Heinkel is adapted (cp. section 2.2.1) (Heinkel, 2000, 7-9). Figure 2.1 includes the production factors of goods production and therefore is suitable to be compared with the

factors presented in figure 2.2 for PDP.

A PDP is used for the operational construction of statistical reports. Direct and indirect factors are able to be divided as in goods production (see figure 2.2). Indirect factors can be described as planning and controlling production. The direct factors of PDP are manpower, consumption factors and facilities.

The input factor in PDP is source data. The output factor is aggregated information derived from the source data and presented as statistical reports. For the transformation of input into output factors, workers and processing facilities are necessary. Operating supplies are not lubricants in PDP because there are no machines as in goods production except computers. Correlating to IT for example, operating supply in PDP is energy used for supplying the production servers.

C.   Features of PDP that deviate from goods production

C.1.   Aggregation and separation

$f()=\text{sum}()$
$g()=\text{division}()$

aggregation $f()$

delivery period	product	quantity
week 01/2005	a	11
week 02/2005	a	18
week 03/2005	a	14
week 04/2005	a	13
month 01/2005	b	54
quarter 01/2005	c	213

intermediate period (monthly)	product	quantity
month 01/2005	a	56
month 01/2005	b	54
month 01/2005	c	71
month 02/2005	c	71
month 03/2005	c	71
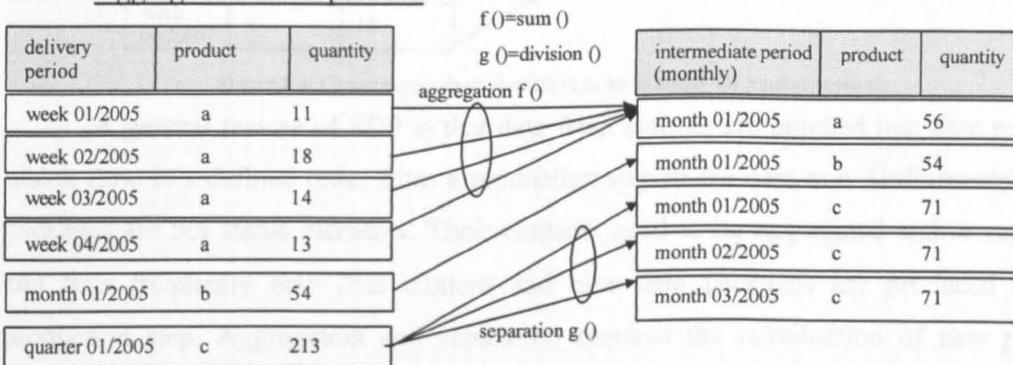
separation $g()$

Figure 2.3: Aggregation and separation on data sets in an example for market research

Aggregation and separation are important operations in PDP. Aggregation is a method used in databases as an operation for condensing input data into output data, with the help of a function (e.g. summation) (Oracle Corporation, 2006, p. Glossary-1). In the example presented in figure 2.3, four calendar weeks of product 'a' are summed. The result is a single data set with the turnover quantity of the first month of the year. Aggregation is comparable with the sub-types in goods production where non-isolatable intermediate parts are used. After an aggregation, the source data sets can no longer be easily identified. This circumstance is intentionally desired to allow, for example, anonymous end reports.

Separation is a reverse operation, where, for example, from a single data set, several output data sets are generated by operations such as divisions or pro-rating. For example, in figure 2.3, starting from a single data set that contains the turnover quantity of a Quarter of product 'e', several data sets are created, where each represents a month and contains one third of the turnover quantity. Separation means to portion specific values. An

analogous example in chemical goods production would be to split a pulverised substance into small portions for producing single pills.

Both operations specially illustrate what PDP is about, and they are the usual daily work automated in the PDP process. Both of these PDP operations need to be specially treated and considered in PDPM. In reality this characteristic complicates PDPM since tracking the data flow is difficult.

C.2. Changing product identifiers and data package identity

source data packages ⟶ production step ⟶ destination data packages

data package number	delivery_period (part of key)	article_id (part of key)	quantity		data_package number	intermediate_period (part of key)	article_id (part of key)	quantity
1	week 01/2005	A	11		5	month 01/2005	A	56
2	week 02/2005	A	18	aggregation f ()				
3	week 03/2005	A	14					
4	week 04/2005	A	13					
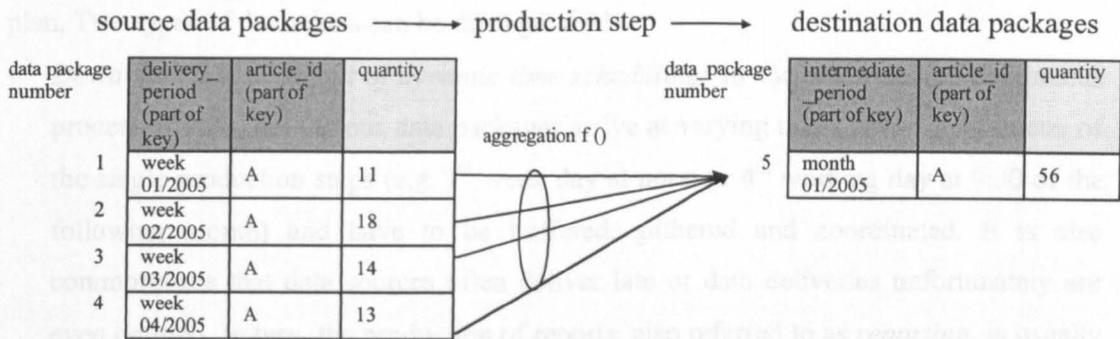
Figure 2.4: Changing product identifiers in an example for market research

A general feature of PDP is that data from sources are bundled into data packages which flow in a defined order from a production step to the next one. Unfortunately, data packages are not stable elements. Their contents need to be aggregated and/or separated and thus frequently new data content and new data packages are produced after a production step. Aggregation and separation requires the introduction of new *product identifiers* during the processing. Product identifiers are the identification keys of data and data packages. In the example in figure 2.4 identification keys of the four source data packages are the *delivery period* and the *article_id*, or after the aggregation, the single destination data package is identified by the *intermediate period* and the *article_id*. In this example, weekly data is aggregated to monthly data. This aggregation of periods is done for an item with the article_id 'A' which is for example a 'TV x from Sony'. In reality not only periods are aggregated, but other parts of the product identifiers as well. Moreover, a production step which executes the aggregations and separations can have one to many source data packages and one to many destination data packages. This example shows that PDPM needs to cope with the fact that data packages change their identities as they proceed through the PDP process.

C.3. The difference between periodic data and master data

There is a difference between the incoming periodic data and the master data in a PDP process. The periodic incoming data is collected in intervals from the different

sources. This data includes *facts* (Oracle Corporation, 2006, p. Glossary-6) such as for example, sales values and it is examined for *unknown items* (e.g. unknown brands). If unknown items are found, the master data usually needs to be extended. Master data is the *auxiliary material* with which the incoming periodic data is compared. Master data, for example, can be the item identification or brand.

C.4.   Deviations

A characteristic of PDP is the large number of deviations against the production plan. Two types of deviations can be distinguished:

- *Deviations that arise out of dynamic time scheduling:* In the never-ending continuous process of PDP, the various data packages arrive at varying times at the input queue of the single production steps (e.g. 1st week day at noon or 4th working day at 9:30 of the following month) and have to be buffered, gathered and coordinated. It is also commonplace that data sources often deliver late or data deliveries unfortunately are even omitted. In turn, the production of reports, also referred to as *reporting*, is usually time independent from data collection and thus also needs accurate planning to prevent uncoordinated production when deviations appear. As similar deviations also occur in goods production, there are scheduling algorithms which can be found in the operational research area (French et al., 1986, 78-91).

- *Deviations can also arise out of dynamic changes of input data:* While gathering the input data for a statistical report, single values of the sample are not important. The same statistical report can be produced by using different sample data. In PDP a deviation can be to replace a data package, as data packages specify the used sample. However, these deviations do usually not change the results contained in the statistical reports. These deviations often emerge during run time and cannot be foreseen reliably. As they occur usually unexpected, expert knowledge is required to handle them. An example for this type of deviation is that the data packages can be substituted if they fall below a defined quality standard or if the deliveries from the sources are late. However, these deviations are unique in PDP due to the statistical nature of the reporting and additionally complicate the supervision processes.

C.5.   Data Storage and Transfer

An advantageous difference between goods production and PDP is that PDP does not require expensive stock-keeping controls of (intermediate) goods. Stock-keeping in goods production is often very expensive and requires sophisticated control mechanisms

and storehouses to coordinate input and output of a production step. Comparable stock in PDP is normally storage on a computer system, which is proportionally inexpensive.

Data transport is not accomplished utilising lorries via motorways, but is sufficiently achieved over networks and electronic transfer mechanisms. Storing and transporting data is expeditious and compared to goods production inexpensive, and is therefore not a bottleneck in PDP, but definitely one in goods production. Planning production in PDP can thus be reduced to planning the scheduling of production jobs and resources as well as concentrating on planning production costs.

D.   Periodicity in PDP

In order to enable timelines in the end-reports, reporting is repeated in intervals (e.g. weekly, monthly or bi-monthly). These reporting intervals can differ from the data acquisition intervals. For example, data sources can deliver on a weekly basis, but the report can show monthly results. Vice versa, monthly data deliveries from the sources can be used to create reports which show weekly results. This is a push- and pull-mechanism. Data acquisition pushes in intervals data into the PDP system. Reporting pulls the data in order to achieve reports in separate intervals. The consequence is data acquisition and reporting can be done to different times. In addition, as usually the reports are sold to customers over a specific timeline (e.g. each month a report is delivered for one year) the deadline for delivering a report is repeated in intervals (e.g each 10th of the month a report has to be delivered to the customer). Since a main goal in PDP is to meet delivery dates of reports in order to gain customer satisfaction, report deliveries, reporting, and data acquisition have accordingly to be coordinated.

E.   PDP systems

In general, PDP systems for computerized support of PDP are complex mixtures of traditional production systems and data processing systems. A PDP system consists of hardware and software elements. Hardware elements are, for example, production servers and the networks between them. Software elements are the operating systems, the utility programs (e.g. mechanisms for data transfer) and the production components used on these servers. Production components are software programs used for processing the input and intermediate data. Each of them represents a production step. All production steps together build up a production chain. The production chain is a workflow and can be compared with a huge *data-pump*, where data is aggregated, separated to finally create information in form of statistical reports.

PDP systems can be found where continuous data warehousing processes are used for interpreting data from different distributed sources, in different time periods and usually where very large data volumes need processing. An example can be found in market research (Ruf & Kirsche, 2005) where data from retailers are gathered to produce periodic reports concerning competition, demographic evaluation of subsidiaries or product sales league tables (see appendix B). Another example is the gathering and analysing of similarly large data volumes for recurring local weather reports.

explained in sub-section	goods production	data production
A, B, C.3	material	data, periodic data
A, B	raw and intermediate material items	raw and intermediate data items
C.2	bundle of material	data package
C.5	material transport	data transfer with data transfer mechanisms
C.3	master data	master data
A, B	product (output)	statistical report (information)
A, B	product planning	end-report definition: a) carrying out a basis study, b) sample determination, c) determining extrapolation formulas
A, C.4, C.5	planning production: a) planning the scheduling of production jobs and resources, b) planning resource transport and storage, c) planning production costs	planning production: a) planning the scheduling of production jobs and resources, b) ---, c) planning production costs
A, B	material procurement	data collection
C.5	stock-keeping	hard disk storage
A	lot-size	number of end-reports
A	workflow definition	workflow definition; data packages flow in a defined order through the PDP system
A, C.2	parts-list	end-report definition
C.2	identification key of a product part	identification key of a data package
C.1	fusion of parts	data aggregation
C.1	fragmentation of parts	data separation and duplication
A, E	production step	production step, data processing step
E	production program, IT-support for a production step	software component which represents a production step
A, E	production chain	production chain, data-pump
C.5	assembly lines	data transfer via networks
A, D	production of product variants in intervals	periodic PDP
C.4	deviations that arise out of dynamic time scheduling	deviations that arise out of dynamic time scheduling
C.4	---	deviations that arise out of dynamic changes of input data

table 2.1: Association of terms in goods production and PDP

F. Differences in terminology between goods production and PDP

For summarizing the discussion of PDP concepts and for providing a deeper understanding, the terminology used in goods production is compared to the terminology used in PDP is depicted in table 2.1.

2.2.3 Goods production management used as metaphor for periodic data production management

The metaphor of the desired PDPM to the traditional production world is goods production management. Its concepts are explained in the following:

A. The most important basic concepts of goods production management

Goods production management is concerned with control and management of production processes, from planning through assembling, testing, and to end-control, including the final product delivery to customers. Beyond ensuring that the production process is unobstructed, management normally uses key performance indicators and business ratios to monitor and control the progress and productivity in production (Maennel & Weber, 1982, 597-588). Especially, strategic, tactical and operational management have a deep interest in information concerning production. Relevant issues for observation are *timing, costs, resources and quality*. Production management desires in relation to these issues to ensure that production is as much traceable and provable as possible. Subsequently, production management is closely related to quality control (in fact those two activities intersect) and is deployed to assist the production of high-quality products in order to improve customer satisfaction. TQM (total quality management) is an example of an approach in this area (Fuermann & Dammasch, 1997).

B. Sketch of a goods production management system
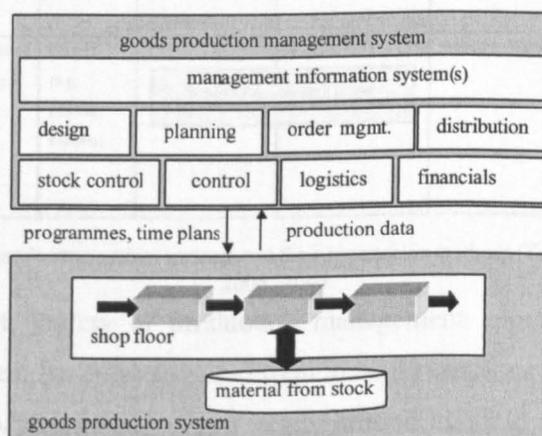
Figure 2.5: A goods production management system (adapted from Kurbel, 2003, 299)

As the system design concept sketched in figure 2.5 indicates, production management systems are concerned with designing products, planning production, handling orders, distribution of products, controlling stock and production, material logistics and managing finances. Production programmes and time plans are communicated to production machines. In return, the machines communicate production

progress and status to the management system.

C.   Goods production management systems

Goods production management systems are referred to as production planning and control systems (Kurbel, 2003, 15 et sqq.). Their aim is to provide IT-aided supervision of production processes. Such systems are PPS systems (production planning systems) (Kurbel, 2003), ERP systems (enterprise resource planning) (Bernroider & Koch, 2000) and/or WFM systems (Workflow Management Systems) (Leymann & Roller, 2000). These approaches are described in more detail and are discussed in chapter 3 and chapter 4 in relation to their applicability as PDPM system.

production type	example	input	output	supervision/ control	shop floor planning	product design rule	speciality
sensor-oriented	power plant, refinery	e.g. coal	power	sensors: power, gas, temperature, pressure	control room	power demand of customers	continual production
goods-oriented	car manufacturer	e.g. steal, screws, products from suppliers	cars in different variants	factory data capture, supply chain management	shop floor planning software, production planning systems	parts lists, customer orders	demand or order based production
receipt-oriented	chemical industry	chemicals	chemicals	sensors	control room	receipts, customer orders	inseparable mixtures
package-oriented	mail-order-houses	e.g. books	package	inventory information system, supply chain management	shop floor planning software	customer orders	surveillance supported through IT
data-oriented	statistical observations, market researchers, weather forecasts	observation data (e.g. retailer data)	reports (e.g. market reports)	?	?	customer orders	periodic production, changing primary keys, data aggregation, statistical business, IT-based processes

focus in this research project

Table 2.2 : A selection of production system variants and their supervision methods (Schanzenberger & Lawrence 2005, 204)

There is a high variety of production management approaches because of the various production types. An overview of current vendors can, for example, be found at the internet-platform "IT-Matchmaker" where yearly around hundred new ERP/PPS systems are registered, each with perhaps hundreds of features (IT-Matchmaker, 2005).

Examples for the different supervision techniques are listed in table 2.2.
The differences as seen in the *supervision/control* and the *shop floor planning* columns, relate to the diversity of demands. While most production systems have well documented and proven supervisory systems as indicated in the table, supervision approaches in PDP still have to be established.

(Schanzenberger & Lawrence 2005, 204)

2.2.4 Periodic data production management

The focus in this thesis is to provide effective and sustainable system design concepts for PDPM. In this section, PDPM is introduced. The differences between the metaphor goods production management and PDPM lead to problem areas and points of interest in this research project.

A.   The most important basic concepts of PDPM

PDPM aims to provide (IT-aided) supervision of PDP. PDPM is concerned with management of production from planning, through processing and handling deviations, to end-control, including the final report delivery to customers. PDPM additionally includes process management, error handling and system status information. Moreover, management usually uses key performance indicators and business ratios to indicate the progress and productivity in production. Especially, strategic, tactical and operational management is concerned with gaining detailed insight by using key performance indicators. They are interested in the following features which have to be supervised: *timing, costs, resources and quality*. These features need to be planned, monitored and controlled. Thus, the most important basic concepts of PDPM are *planning, monitoring and controlling* PDP. These three concepts are the cornerstones of PDPM as well as of goods production management. However, the appropriate approaches based on these concepts are dissimilar because of the different natures of the underlying production system types. For example, the process of gathering operating data in goods production from the production machines usually requires additional hardware (e.g. sensor techniques) and is thus somewhat different from logging protocols in PDP. Accordingly, the investigation of these differences is necessary.

B.   Sketch of a PDPM system

A PDPM system should comprise a management information system and units for planning, monitoring and controlling the underlying PDP system as shown in figure 2.6. This initial sketch of the required system is related to the description of a goods production management systems provided in figure 2.5.

The extent of communication between the PDP and the PDPM system varies in potential approaches (see chapter 5). One extreme variation is that detailed production information may be transferred in both directions, considering the other extreme variation as communication may be limited to answering simple queries on production status.

It is necessary to define this rough illustration of the above system design concept in more detail. Accordingly, a more advanced description of the system components involved, has been devolved during this research project and will be presented in chapter 5.
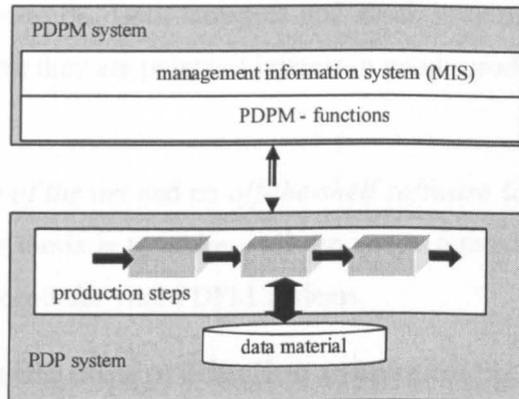
Figure 2.6: Initial PDPM system design concept

C.   Enumeration of most desired achievements of PDPM

PDPM has to deal with specific PDP processes (see section 2.2.2) as, for example, aggregation and separation. Thus, an important need is to cope with the fact that data packages change their identification keys during production. This is the reason why PDPM should be able to track the *flow of data* in the production process. Data flow tracking is necessary because it provides *transparency* of the production process. However, static tracking of the data flow is not enough, as the frequent dynamic deviations at run-time must be considered. I would be an advantage *to automate the planning* as much as possible, despite the numerous deviations, since production cycles over different periods are largely repetitive. This can save manpower and therefore results in reduced expensive manual effort.

PDPM aims for traceable and provable production. Consequently, *transparency* of the production process and data quality are essential goals. This is particularly important for PDP as the intermediate and end-products cannot be tested. A statistical report is not provably good or bad. For example, it is not provable whether an accurate sample was used, whether the data sources delivered useful data or if the data operations during processing have been correct.

The *comparison of previous, current and predicted future production status* is required. Furthermore, aggregated production overviews are required. They can be created by summarising the production status and can be presented in form of *key performance indicators* in appropriate overviews. However, the commonly known key performance indicators from the metaphor goods production have to be re-interpreted for their use in

PDPM (see section 2.3.4). For example, the interpretation of transfer/transport times is different between goods production and PDP durations. In goods production transportation is time-consuming and expensive. In PDP transfer/transport times are the times where data are transported over the network. Data transport and stock-keeping play less important roles in PDPM, but of course they are points of interest in goods production management.

D.   PDPM systems

As there is no *state of the art* and no *off-the-shelf software* for the management of PDP today, the aim in this thesis is to address all the issues figured out and to introduce relevant system design concepts for vital PDPM systems.

2.3   Analysis of periodic data production management

The analysis of the PDPM is an essential precondition for enabling a substantial and creative search process for sophisticated system design concepts. Thus, in this section the aim is to provide the results of the detailed analysis for PDPM. The analysis results have been derived from studying real-world PDP business processes, discussions with involved personnel and participant observations.
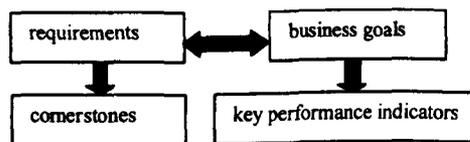
Figure 2.7: Overview of the analysis for PDPM

Figure 2.7 depicts that this analysis has been achieved by investigating the business goals and the requirements of PDPM (see section 2.3.1). The requirements have been investigated to discover the business goals and the goals determine the requirements (see section 2.3.2). The cornerstones of PDPM are discovered and will answer the question of how the requirements can be put into practice (see section 2.3.3). To measure the progress during production the most interesting key performance indicators concerning time management have been identified (see section 2.3.4). This was necessary for the evaluation of the business goals.

2.3.1   Functional requirements

In this section the main focus is to present the essential properties in PDPM. These functional requirements concentrate primarily on the timing aspects, as production scheduling demands that reports be delivered on time. The requirements have been defined by investigating approaches described in literature, observing real-world PDP processes

and by gathering requirements from involved individuals. An outcome of this research project is that substantial PDPM must focus on the following issues (published in Schanzenberger & Lawrence, 2005, 9-11):

a. **Status:** Status relates to the progress of processing of a particular data package. The status of a data package describes how far it has been processed within the production chain. This assumes that all predecessor data packages have been processed through all former processing steps and that this particular package has now been processed up to a point of interest with a defined degree of completion. Furthermore, the planned and current due dates of the data packages need to be fully transparent. In PDPM it is adequate to concentrate on pure status information. There is neither need to supervise every single step and activity nor is there need to instantiate workflows, to check the status. Detailed modelling and visualization of workflows to achieve the status are not needed. PDPM is more abstract and is thus beyond the scope of WFM, possibly dealing with hundreds of thousands of action instances.

b. **Quality:** Quality in PDPM is a function of the production progress and its (data) ingredients. The sought-after quality is a maximum of available data sources within the allotted schedule. PDPM should be able to explain and document quality. Transparency of the production process is thus necessary to assure good quality of the product.

c. **Aggregations, separations and unstable product identifiers:** Data aggregations are part of the very nature of PDP. Multiple data packages are for example aggregated into one resulting data package. Separations split single data packages. Aggregations as well as separations are normal, useful and required in PDP (see definition in section 2.2.2). Both aggregation and separation are also instruments for PDPM. They allow more compressed or filtered overviews of the extremely high volumes of data. However, they can be responsible for a reduction of detailed production information. Thus, these instruments should be very carefully used (e.g. in overviews where detailed production information are not the focus).

Time scheduling is not trivial in PDP, due to frequently changing product identifiers of the intermediate data. In database terms, the data packages with their primary keys are transformed into new content and therefore lose their original primary keys. Consequently, a data package is not a static element from the beginning to the end of the process. For example, incoming data packages might have 'delivery periods calendar week 41 – 44' as part of their primary key. The resulting data package is an aggregation with the primary key part 'reporting period October 2004'. Subsequently, it is crucially important during the process that despite of the transformations of data packages inclusive their primary keys, PDPM shows the relationships between the data packages during the entire process.

d. **Deviations:** Deviations are usual in PDP (see definition in section 2.2.2). They can be caused by dynamic changes in data sources. Statistically proven it is normally good enough as changes in data sources will still lead to the same result. These deviations must be carefully managed to manually or automatically find the best replacement for the missing data. Deviations can also arise out of dynamic time scheduling and can, for example, be triggered

from delayed data material. Numerous deviations of both types emerge during run-time and thus immensely complicate the supervision of the PDP process. As a result, PDPM needs the competence to handle and revise plans, and to manage deviations from the plan.

e. **Exception reporting:** Exception reporting in form of event handling supports production error detection and prevention. A sound PDPM has to cover these issues. Due to the large number of data packages in the production chain, the focus should be on exceptional behaviours and events. The aim is not to prove every single activity but to assure smooth production. Consequently, operational PDPM has to concentrate on exception reporting.

f. **Repetition:** A PDP includes repeated data production processes. PDPM should make use of this property in planning of due dates. For example a rule could be '4.th working day of the next month'. The planned due date of a data package associated with this rule is then assigned each month to a specific date. Accordingly, providing planned due dates for data packages can be fully automated. Actual completion dates of data packages can also be automatically updated by regularly querying the production.

g. **Monitoring instead of control:** PDPM should concentrate on monitoring production progress and management rather than undertake direct corrections in production. This is important as PDP systems should run fully independent from their PDPM systems, due to the demand never to slow-down production caused by any functions or events from other systems. However, manual corrections in production can be based on information collected by PDPM systems.

<div align="right">(Schanzenberger & Lawrence, 2005, 9-11)</div>

To summarize, PDPM should focus on showing the data flow rather than the control flow, and on showing the data dependencies with respect to the changing product identifiers. Additionally, PDPM requires planning and monitoring of timing with respect to the run-time deviations as well as providing production progress degrees for data packages. Instruments for exception reporting are a good choice to provide management information in order to cope with high data volumes.

2.3.2 Challenges and business goals

There are several challenges which lead to the fact that establishing sophisticated PDPM is difficult. In this section the major challenges are outlined and confronted with the main business goals as to why industry is interested in implementing computerized supervision. Designers who are interested in establishing PDPM can use and extend this list which might help them to weight the advantages and disadvantages and to decide whether their interests justify implementation and costs.

Challenges

The following main challenges can be identified in PDPM and are published in (Schanzenberger & Lawrence 2005, 203-217):

o   Many functionalities are desired in a PDPM system. Hence, PDPM systems need to be complex multi-part systems in order to fulfil a complete surveillance of PDP systems.

o   In most of other management system types the control flow is tracked. However, in PDPM the main interest is to observe the data flow. Tracking the data flow is much more difficult because keeping data dependencies for surveillance is necessary and overcoming the changing of product identifiers is required.

o   After aggregations and separations the identification of the numerous data sources is complex (see section 2.2.2, point C1) (A detailed investigation of this fact and possible identification processes can be found in (Schanzenberger & Tully & Lawrence, 2003, 544-557)). The dynamic restructuring of data is reason enough for rejecting approaches for simple life-cycle-management.

o   The expected countless dynamic deviations at run-time are uneasy to handle.

o   A full automation of PDP is usually not possible. Many issues remain manual tasks as, for example, deciding to replace a data package due to quality reasons. These manual tasks need to be supported by PDPM. Unfortunately, they can also be seen as obstacles for a full automation of PDPM.

o   PDP systems are usually distributed and run parallel on several production servers. This complicates PDPM for all participants.

(Schanzenberger & Lawrence 2005, 203-217)

Business goals

PDPM is relevant for industry, because the following business goals can be supported with those tools in relation to time management. In the long run this reduces production costs. The detected business goals have been published in (Schanzenberger & Lawrence 2005, 203-217):

o   "You cannot control what you cannot measure" (DeMarco, 1982)
    This statement from DeMarco explains the importance of measuring PDP. This measurement of production information can easily be automated in PDP by using logging approaches. The result is world-wide gathered management information can be standardised, (i.e. using everywhere the same automated methods to gather information, always using the same automated calculations and procedures for presenting key performance indicators to management, etc.).

o   Gathering operational, tactical, and strategic information for different management levels can be ensured. This information helps by identifying strong and weak points in production and provides as a result decision support for management. Thus, the manoeuvrability of an organisation can be increased.

o Throughput- and waiting times can be reduced by optimisation. A reduction of time usually means a reduction of production costs and thus a positive return on investment.

o Available and free resource capacities (data, server, or human) can be easily identified (if corresponding assignments between data, servers and humans are provided) because PDPM offers analysis. Consequently, open potentials of resources can be discovered. Using open potentials can lead to balance the workload, enlarge the product range and usually increase the profit in the long run.

o The creation of production plans should be automated. The repetitive character of PDP can be excellently used to achieve this automation. By applying automatic plan creation, workload can be reduced. A high automation level ensures rapid production, offers error prevention and supports independence from staff's expert knowledge.

o PDPM needs to be able to guarantee and improve product quality by increasing process transparency. Transparency is important in PDP as the end product *report* cannot be tested. If a report is good or bad is not always determinable. Customer retention can be increased when a fully transparent production process demonstrates reliability and product quality. Arguments for attracting new buyers are then substantiated. In the long run the position against other competitors can be strengthened by supporting a transparent production process.

o Changes in the PDP system should be avoided. The required PDPM system should be able to observe the PDP processes without changing the included legacy programs (i.e. production steps) to save development costs. A high degree of independence between the PDPM system and the observed PDP system is desirable.

(Schanzenberger & Lawrence 2005, 203-217)

2.3.3 The cornerstones

The description answers the questions of how PDPM can be carried out and what is needed to establish such a computerized supervision with a high automation level. The result is that planning, monitoring, and controlling are the essentials of a sound PDPM (see figure 2.8). These results presented in this section are also confirmed in a pre-study (see appendix A.3) (Lehner, 2002, 10-12) which was supported by this research project.
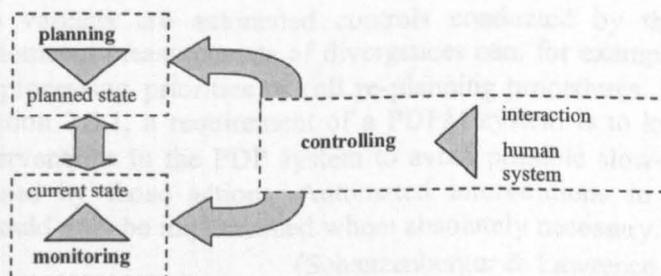
Figure 2.8: Cornerstones for supervision (cp. Lehner, 2002, 10-12)

Planning:

For facilitating a provident production the objects need to be specified which need to be produced in the next time. This includes rough and detailed planning. For rough planning usually so-called *data-orders* are derived from

the definitions of end-reports. Each specifies the data content, which is needed to satisfy one or more report's calculation base. These data orders are forwarded to the production operators which are responsible for the entrance of the PDP system, for enabling the punctual import of source data.

Detailed planning includes activity planning and also pins down the chronological order of events. For a successful execution, the data packages need to be at the right production place on time. Thus, detailed planning of PDP should consist of activity and data package (= data content) planning. The production quantities to be managed and critical production days can be derived from visualising those plans. An advanced optimisation of production might only then be achievable. As PDP systems usually process data packages in parallel, the production can be speeded-up if optimisation is emphasised. If, for example, important activities or data packages are prioritised, optimisation is supported, and sorted and prioritised work lists are achievable. Participants could divide easily between important and less important production jobs.

Monitoring:
One of the most important requirements for PDPM is to record production status information. In a PDP system the logging of current processing states can be easily established by using logging techniques. As PDP systems are always communicating with databases this can, for example, simply be implemented by writing the status information in database tables. The log with the current states can additionally be compared to the plan. This is relevant, as one of the most important issue is to measure the difference between planned and actual states. Only if both (planning and monitoring) are provided measuring the difference is possible. Furthermore, when a production period is over, the gathered actual activity duration times can be used as experience values to estimate duration times of following periods. Monitoring includes in the broader sense additionally methods for supporting system health, error prevention, early error detection, and forwarding event information.

Controlling:
If the divergences between the planned and the current production status information are reported, responsible individuals have the chance to intervene accordingly. Consequences might be to re-plan production or to take preventive actions, such as, to raise the priority for processing specific data packages for meeting important deadlines.

Possible variants are automated controls conducted by the PDPM system. The automated measurements of divergences can, for example, trigger adjustments of processing priorities or call re-planning procedures. However, as stated in section 2.3.1, a requirement of a PDPM system is to keep away from direct interventions in the PDP system to avoid possible slow-downs of production caused by those actions. Automated interventions in the PDP system itself should only be implemented where absolutely necessary.

(Schanzenberger & Lawrence 2005, 203-217)

A sound PDPM system can be identified by containing planning, monitoring and controlling approaches. The result is, approaches which do not cover or support all of these three conditions would not completely satisfy the requirements of PDPM.

2.3.4   The most relevant key performance indicators

As production management is concerned about dealing with key performance indicators, the most relevant issues for PDPM are introduced. This key performance indicators are listed in this section because they are referenced in chapter 7 and this overview shall help to indicate the added value which IT-aided PDPM has for company management.

The question to answer in this section is how to find out the productivity and the progress of a PDP. This question is answered when looking into other production management areas. For example, in traditional production management key performance indicators are used to specify the success and healthiness of production (Maennel 1982). The frequent measurement of such values is important to be informed about production progress in these dynamic environments. In PDPM this measurement can be done by IT-supported monitoring and by evaluating the monitoring data. Best practice is to automate the monitoring as the measurements are usually more reliable, straight, and standardized than manual gathering processes (Armour, 2002, 15-18).

This research project is focused on the monitoring for time management. As investigated in section 4.2.1 the key performance indicators, used in traditional time management, need to be interpreted for PDPM. The intention in this section is to enumerate the most important key performance indicators to set up a basis for control possibilities in PDP.

<u>Time management</u>

Kurbel introduces key performance indicators for time management in goods production (Kurbel, 2003, 141-163). Only the most interesting of this non-monetary values are used for the intended interpretation. In table 2.3 a comparison of the terms used in the metaphor goods production management and in PDPM is provided. A description of the terms and an indication of their relevance in PDPM is included.

Throughput time: Due to the changing product identifiers in PDP the throughput time in PDP needs to be interpreted by a unit. A unit can be, for example, a data package where the throughput time is measured from its generation up to a certain point in the production process or by considering its earliest/latest predecessor and earliest/latest successor relationships to other data packages. A unit can also be interpreted as an end-report for which the latest data source needs to be measured up to the end of processing the report. The latest data source is necessary because, for example, in a yearly end-report the

first data source would be delivered for a January-period and thus the throughput time is only interesting from the date where the December-period is delivered to the date when the report has been finished. Throughput times are highly relevant as they can be seen as one possibility for measuring productivity. If throughput times can be minimised free time emerges.

KPI in goods production management	description	KPI in data production management	description / comment	importance in PDP
++: highly relevant, + relevant, - not relevant				
throughput time	"throughput time: the average time that a unit requires to flow through the process from the entry point to the exit point. The throughput time is the length of the longest path through the process. Throughput time includes both processing time and any time a unit spends between steps." (NetMBA, 2005)	equal	in general throughput time is the same as in traditional production. However, throughput time in PDP has to be interpreted for a specific unit.	++
set-up time	"set-up time: the time required to prepare equipment to perform an activity on a batch of units. Set-up time usually does not depend strongly on the batch size and therefore can be reduced on a per unit basis by increasing the batch size." (NetMBA, 2005)	equal	production is guaranteed 24 hours a day. Thus, set-up time in PDP converges to 0.	-
shut-down time	"shut down time: time for switching off and stop the functions of a machine or system" (Ponds-technical dictionary, 2000, 343)	equal	as shut-down times converge to 0, because of the parallel PDP, only turns down times are of interest.	-
down time	"down time: period of time during which a computer system is not working or usable." (Ponds-technical dictionary, 2000, 343);	equal	down time is the time where system parts do not work properly or maintenance work is carried out.	++
transport time	the transport time is the time between the moment that the load unit is ready to be transported and the moment of delivery at the destination. This is the time to deliver product parts from storehouses to product steps or from one product step to the next.	transfer time	the transfer time is the time between the moment that a data package is ready to be transferred and the moment of delivery at the destination. Transfer time in PDP converges to 0	-
idle time	"idle time: time when no activity is being performed, for example, when an activity is waiting for work to arrive from the previous activity. The term can be used to describe both machine idle time and worker idle time." (NetMBA, 2005)	waiting time	waiting time is throughput time minus processing time; waiting time is the time when a data package is not processed	++
Production time/ processing time	"processing time: the average time a unit is worked on. Processing time is throughput time minus idle time." (NetMBA, 2005)	processing time	processing time is throughput time minus waiting time; processing time is the time a data package is processed	++

Table 2.3: Comparison of time-related key performance indicators

Set-up time and shut-down time: PDP runs on production servers which are organised to run in parallel. Usually there is no time where production is not guaranteed. Appropriately, set-up and shut-down times in PDP are not considered.

Down time: The ability to assign down times to production delays that have been caused by these down times, is desirable but usually hard to achieve. A possibility for

considering known down times in advance is to recalculate estimated completion dates. Workers would then have the chance to react accordingly.

Transfer time: Data transfer is usually provided in the range of some milliseconds. Only if networks are broken this information might be of interest for delays. Usually transfer time does not need to be considered.

Waiting time: The most optimisation potential might exist in the area of waiting times. Waiting time appears in PDP when data packages are waiting for processing (production bottleneck), if workers need to manipulate the data (manpower bottleneck), or if coordination between workers need to be dealt with (coordination bottleneck). The reduction of waiting times is thus highly relevant for PDPM.

Processing time: The time production steps need to process the data or if workers manipulate data is called processing time. The processing times of product steps can easily be measured in contrast to measuring the processing time a worker needs for a specific data package. Measuring a workers processing time could only be implemented when the assignments of the data packages to the workers are logged, but this is usually a problem of data privacy. As it can occur that a worker deals with several data packages at the same time, it would also not be clear how the work for each has to be weighted. However, minimizing processing time is interesting in PDPM. This can be done by optimising the programs of production steps by supporting the workers or sometimes by adding manpower.

Other related key performance indicators

Important in PDP is to measure the reliability of suppliers, of the process, and of the product delivery. Another value of interest is the production intensity. This is important for measuring production critical days. To be able to indicate if production is running well or not the value of productivity is essential (see table 2.4).

Supplier delivery reliability: The reliability of suppliers is usually hard to influence in PDP. For example, in market research of retailers, PDP is dependent on punctual getting data from retailers all over the world. There are many reasons why data packages are not delivered in time, as for example, reorganisations of the retailer's IT-systems. If data packages are not available when they should be processed, usually they are replaced by others (cp. section 2.2.2, point C.4). However, the punctual input of source data at the PDP-systems entrance needs to be guaranteed when source data are available. The due date is communicated in form of data orders. The completeness and the delays of data orders

can be measured.

Process reliability: The precondition for process reliability is process transparency. Only if processes are made visible and if they can be overviewed process reliability can be assured. The focus is on the one hand on unobstructed production process and on the other hand on the adherence of due dates. Possible measurements of this value can be to count production events and the time for handling them, and measuring the delays of data packages during the process. Both measurements are highly relevant for PDPM.

KPI in goods production management	description	KPI in data production management	description / comment	impor-tance in PDP
++: highly relevant, + relevant, - not relevant				
reliability: "the degree to which the scores of every individual are consistent over repeated applications of a measurement procedure and hence are dependable, and repeatable." (Questionmark Corporation, 2005)				
supplier delivery reliability	supplier delivery reliability is the reliability of suppliers	equal	usually, it is difficult to influence the reliability of data source deliveries. The influence to change it converges often to 0	+
process reliability	process reliability is the reliability of an unobstructed production process; the adherence of due dates	euqal	reliability of an unobstructed production process; the adherence of due dates	++
product delivery reliability	product delivery reliability is the reliability of delivering the product with a high quality and in the right time.	equal	reliability of delivering the product with a high quality and in the right time; provided by data quality mechanisms, correct extrapolation mechanisms, and due date adherence	++
capacity utilisation	"capacity utilisation rate: an industry's capacity utilization rate is the ratio of its actual output to its estimated potential output." (Canadian Statistics, 2005)	production intensity	"intensity: state or quality of being intense (high in degree); strength or depth." (Hornby, 1988, 444); identifying production critical days with high loads for the production facilities and workers.	++
productivity	"productivity: the amount of output per unit of input (labour, equipment, and capital). There are many different ways of measuring productivity. For example, in a factory productivity might be measured based on the number of hours it takes to produce a good, while in the service sector productivity might be measured based on the revenue generated by an employee divided by his/her salary." (Allied Irish Banks Group, 2005)	equal	number of reports divided by number of data sources or measuring the throughput	++

Table 2.4: Comparison of other key performance indicators

Product delivery reliability: One of the overall goals in PDP is customer satisfaction. This can be assured by reliability in delivering the product on time. Measuring the delivery dates is therefore necessary. Assuring customer satisfaction is also done by assuring the data-quality and correct extrapolations.

Production intensity: Identifying production critical times is a need in PDP. The measurement of the production intensity can help to identify peak times and bottlenecks and in the long run to balance the utilisations. Peak times of servers or production steps can

be logged, but usually it is hard to measure the deployment of workers in PDP due to the lack of assignments between data packages and workers and due to the complexity of weighting the degree of difficulty or heaviness of work.

Productivity: This measurement can serve higher management as a type of traffic light control for PDP. If the productivity is high, the traffic light is green. Is the productivity decreasing (red traffic-light) over a long time, this indicator is able to warn early. The measurement of productivity in PDP can be the number of reports divided by the number of data sources. However, a better measurement in this case would be the indication of the productivity by weighting throughput times or delay times due to the continuous PDP processes.

Key performance indicators excluded from investigation

Not considered in this investigations are monetary performance indicators, which deal with production costs, or the resource capacity management of material, human resources, and servers. This is not to distract from time management but to limit this research project.

2.4   Chapter summary

In this chapter a description of PDP and PDPM concepts is provided by using the definition of goods production as a metaphor model for PDP (see section 2.2). The reasons are that both production types are based on similar concepts, and goods production systems have well-known concepts where various previous research is available. Goods production and PDP serve for operational construction of goods or services. For this construction, input factors are transformed into output factors. Input in PDP is data, as PDP specialise in the analysis and transformation of large data quantities. Accordingly, the end product is *information* in form of statistical reports. For producing these reports, PDP consists of a periodically repeated workflow. Data packages which are the source and intermediate product parts, flow through this workflow.

PDP instances can be found in industry where large quantities of periodic data are gathered and extrapolated to gain aggregated informational reports. Examples are periodic economic market analysis, data for local weather forecasts, or geological databases.

As goods production and PDP is particularly similar, it is also useful to look at approaches for goods production management when methods for PDPM are to be researched and using them as metaphor model. Both management approaches are concerned with timing, cost and resource management of those production applications. In

both cases planning, monitoring and controlling are the key approaches to establish a (computerized) supervision. The management system is responsible for observing the production system when employing either goods production management systems or PDPM-systems.

The IT-applications for goods production management are also known as production planning systems, enterprise resource planning systems or workflow management systems.

Unfortunately, there is no state of the art system for PDPM, today, as there are also some important differences between goods production management and PDPM. These differences derive mainly from the different natures of the individual production types itself. PDPM has to cope, for example, with natural data aggregations and separations as well as with deviations during run-time and includes therefore special requirements. The demand in the industry and those differences between goods production management and PDPM makes it relevant to research into sophisticated system design concepts for PDPM.

Section 2.3 discusses analysis results of the proposed PDPM system. This analysis has been created by observing a real-world PDP system in a leading market research company. The results are the following: The requirements for a valuable PDPM are checking production status instead of controlling activities, providing process transparency, dealing with the aggregations and separations, coping with the unstable product identifiers, managing the deviations during run-time, reporting of the most important exceptions, taking advantage of the repetitive character of PDP, and offering monitoring instead of automated control possibilities. Corresponding to this requirements business goals are to gain a measurable PDP process and thus to enable process transparency by offering production overviews in order to provide decision support for management. Thus, the cornerstones to put these requirements and business goals into practice are approaches for planning, monitoring, and controlling PDP systems. For reporting the insight gained by these approaches to management, production overviews in form of key performance indicators are of interest. The focus in this research project lies on time management and accordingly the reduction of throughput times and waiting times are emphasised issues.

Chapter 3

Literature review

Chapter objective

     A result of this research project is that periodic data production management is a synthesis of traditional production management and data processing management. Previous research in these areas is introduced in this chapter. Research areas studied include goods production management, scheduling approaches, workflow management, methods for exception reporting, concepts of monitoring systems, multi agent system approaches and traditional project management. Subsequently, interesting combined approaches described in literature are presented. However, there is no approach which fulfils all the requirements of IT-aided periodic data production management.

3 Literature review

3.1 Introduction

This chapter provides an overview of existing research and approaches for establishing and practicing PDPM. Section 3.2 identifies research areas of interest (i.e. approaches within information system practice) in literature. The chapter reviews the related single model approaches. As planning, monitoring and controlling PDP comprises multifarious functionalities, it is indicated to look into research for combined model approaches. The combined approaches which are interesting in relation to PDPM are introduced in section 3.3.

3.2 Identifying research areas of interest in literature

A PDP system is a special mix of a traditional goods production system and a data processing system. Accordingly, it is appropriate and opportune to investigate the management techniques for both of these system types. For this reason, in this section, research areas of interest are identified from literature. These research areas were investigated for relevant approaches within information system practice. The approaches are described and are investigated for their relevance in delivering management systems for PDP.

For offering a comprehensive overview, in section 3.2.1 a classification of the suitable approaches in the literature follows first. Then, the relevant existing research in these areas is described. The investigation ranges from single model approaches such as production planning (see section 3.2.2), scheduling methods (see section 3.2.3), workflow management (see section 3.2.4), exception reporting (see section 3.2.5), monitoring system approaches (see section 3.2.6), concepts of multi agent systems (see section 3.2.7) to traditional project management (see section 3.2.8).

3.2.1 Taxonomy of the single model approaches

In this section an overview of the research areas of interest and their related approaches is provided and the reasons for the importance of the approaches in relation to PDPM are introduced. Additionally, peripheral areas are mentioned for reviewing which approaches and why some approaches are excluded from the investigations. In this section

only the single model approaches are discussed, in contrast to combined model approaches (see section 3.3).
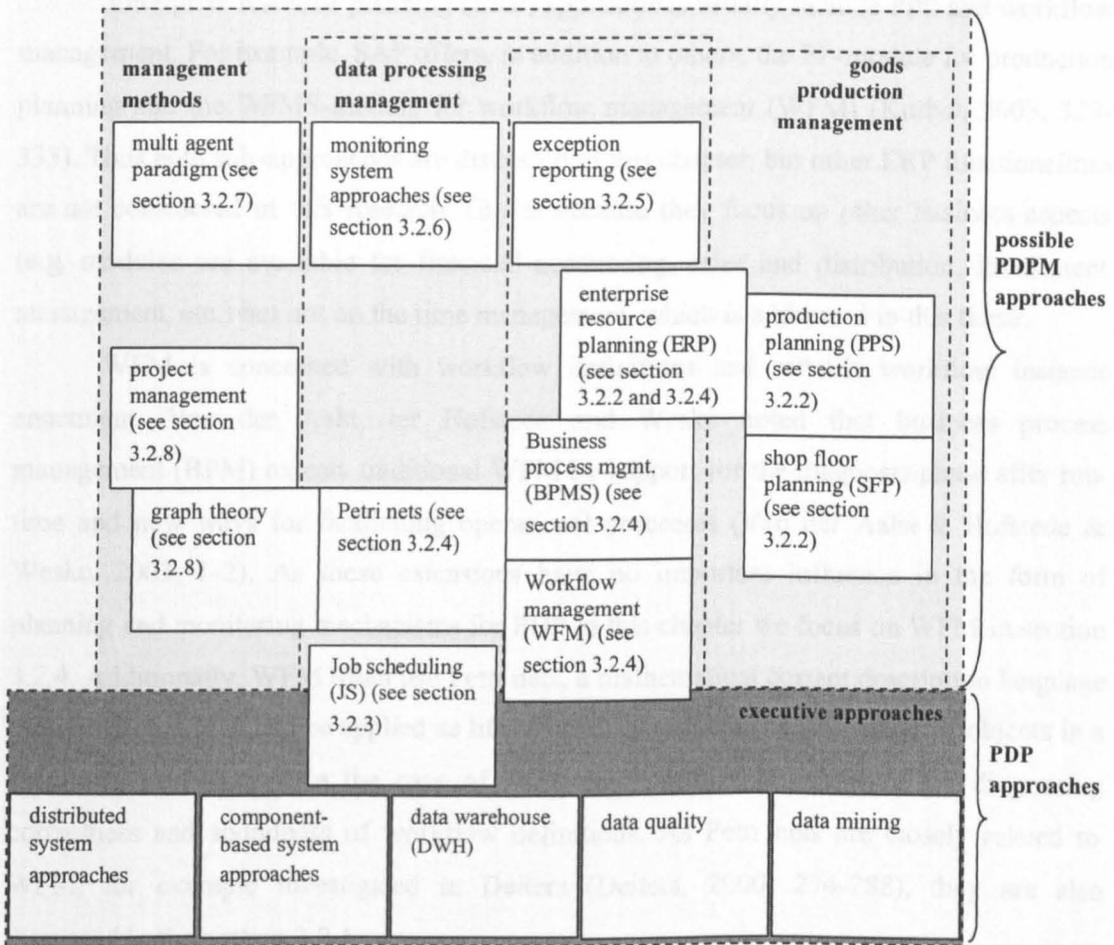
Figure 3.1: Taxonomy of research areas of interest for PDPM

The graphic provided in figure 3.1 classifies possible areas of interest for this research project. A description of this classification follows and is provided by interpreting the graphic from right to left. Approaches, which touch each other, are strongly related, or include, or interact with each other. Moreover, some of the approaches cannot be unambiguously classified into a single category as their applications are used in different areas.

Among all available management methods, data processing management and goods production management methods offer most of the potential approaches, due to their high affinity to PDP.

Under the umbrella term *goods production management*, production planning (PPS) and shop floor planning (SFP) can be identified as relevant approaches. Weight explains that applications of PPS and SFP can be often found together, as PPS can be seen

as rough planning production and SFP is detailed planning (cp. Wight, 1984). These approaches are discussed in section 3.2.2.

Enterprise resource planning (ERP) applications usually include PPS and workflow management. For example, SAP offers, in addition to others, the PP-module for production planning and the WFMS-module for workflow management (WFM) (Kurbel, 2003, 329-333). Thus both sub-approaches are discussed in this chapter, but other ERP functionalities are not considered in this research This is because they focus on other business aspects (e.g. modules are available for financial accounting, sales and distribution, investment management, etc.) but not on the time management which is addressed in this thesis.

WFM is concerned with workflow definitions and reliable workflow instance enactment. Van der Aalst, ter Hofstede and Weske noted that business process management (BPM) extents traditional WFM by support for the diagnosis phase after run-time and new ways for facilitating operational processes (Van der Aalst & Hofstede & Weske, 2003, 1-2). As these extensions have no important influence in the form of planning and monitoring mechanisms for PDP in this chapter we focus on WFM in section 3.2.4. Additionally, WFM often use Petri nets, a mathematical correct description language of processes, which can be applied as life-cycle management (i.e. snapshots of objects in a chronological order or in the case of PDP: data package tracking) or for diagnosing correctness and soundness of workflow definitions. As Petri nets are closely related to WFM, for example investigated in Deiters (Deiters, 2000, 274-288), they are also discussed in the section 3.2.4.

Another research area which can be seen as an approach for both, data processing and goods production, is *exception reporting* (e.g. Shamsuzzaman & Lam & Wu, 2005, 1298-1305; Klein & Bar-Yam, 2001, 9-12;). This area is discussed in section 3.2.5.

Under the umbrella term *data processing management*, monitoring system approaches and job scheduling (JS) are important and relevant for this investigation. An examination of relevant monitoring systems (e.g. Kurschel, 2000; Rackl, 2001) for PDPM can help to advance the discussion (see section 3.2.6).

Brucker discusses that JS systems are interesting approaches for executing data processing jobs to pre-defined due dates. The concepts used can be summarized as JS algorithms (Brucker, 2001). These attractive planning approaches are investigated in relation to PDPM in section 3.2.3.

Management approaches which cannot be classified into the category of data processing or goods production management are multi-agent systems, project management

and graph theories. Ferber explains that multi-agent systems can be applied in many different application fields and are a potential option when different agents need to interplay together for the control of any objects (e.g. networks) or for executing any tasks on their own (Ferber, 2001) (see section 3.2.7).

Project management is usually not used for computerized supervision of periodically repeated projects (cp. Turner & Mize & Case, 1987, 353-355). However, the concepts of project management are appealing as they are strongly related to the items of interest in PDPM: timing, cost and resource management. These concepts are thus highly of interest for investigation in relation to PDPM and are introduced in section 3.2.8.

Petri nets as well as project management use graph theories and algorithms as basics (cp. Baumgarten, 1996, 22-44; Brucker, 2001, 202-204). This is the reason why graph theories are not discussed separately but are included indirectly in the description of the other concepts.

Approaches which can be identified as executive approaches for conducting PDP itself are not of interest in this thesis. Those researches include distributed system techniques (e.g. Thomas et al., 1990, 237-266), construction of component-based systems (e.g. Stal, 2000, 27), establishing and reporting in data warehouses (e.g. Albrecht et al., 1997, 651-656), finding coherences in data with data mining techniques (e.g. Lusti, 2001) and assuring data quality with data quality approaches (e.g. Hinrichs, 2002) . WFM as well as JS include parts for reliable job execution and can thus be also partly classified to the executive approaches. However, both techniques comprise other properties, with far more management possibilities and are thus discussed here.

3.2.2 Production planning systems

It is advantageous to investigate the research in the area of goods production management in relation to PDPM for two reasons. The first reason is to find out, if appropriate systems exist for using them as IT-support for PDPM. The second reason is to find out, what can be learned from the management techniques in goods production. It is expected that experiences can be transferred to advance PDPM. For this reason, in this section, PPS and the closely related SFP approaches are described.

Computer-aided PPS systems for traditional production have been available since the early 1960's. However, PPS is still an open research area as industry is multifaceted and dynamic. Current research in this area focuses on modular architectures, methods

which can be parameterised (Tsai & Lin, 2005, 608-618), and approaches which are able to automatically generate production programs and data structures. A current trend is to use WFM for process-oriented operations in cooperation with PPS approaches (Kurbel, 2003, 337-344).
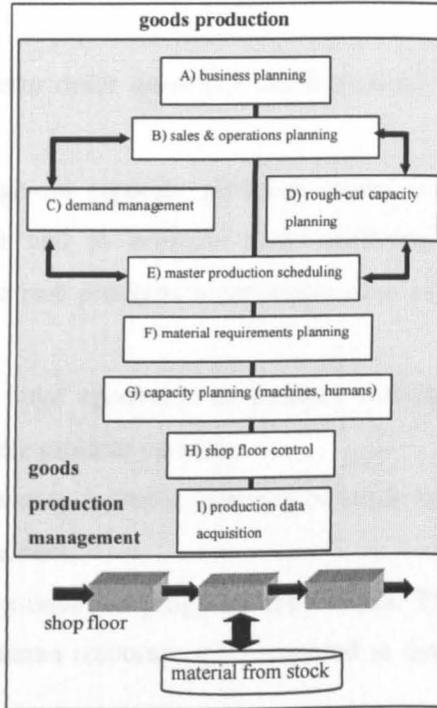
Figure 3.2: MPR-II standard for goods production (adapted from Kurbel, 2003, 110-112)

Due to the high diversity of production types, there is no single PPS system which meets all requirements. For example, FIR the research institute for rationalisation at RWTH Aachen University and the Trovarit AG, a spin-off organisation of FIR offers with the internet platform IT-Matchmaker (IT-Matchmaker, 2005) a categorization of hundreds of vendors which offer products in this area. For providing an overview and a useful possibility to compare system design concepts of PPS systems with the one needed in PDPM, the proven MRP-II (Manufacturing Resource Planning) standard (Wight, 1984; Yang & Lou & Zhou, 2005, 366-371) is used, which is for example underlying the PPS module from the well-established SAP-R3 (Kurbel, 2003, 329-333). Figure 3.2 depicts the MRP-II standard which is roughly descript in the following. All descriptions about the functions in goods production are according to Kurbel (Kurbel, 2003, 110-112).

A) Strategic management is concerned with business and budget planning. This can be seen as very abstract high-level strategy arrangements. For example, such arrangements are estimating and regulating production costs, or planning success strategies. Its aims

are increasing productivity and a costs-aware production, for contributing to business success.

B) Sales and operation planning in goods production is concerned with pre-planning how many products can be sold and what direct factors are needed to meet these quantity goals.

C) Sales volumes and customer order quantities are forecasted and estimated in demand management.

D) In goods production rough-cut capacity planning means to overview the demand of machines and manpower and to estimate their workload. This can be done, for example, by analysing the past production capacities over a timeline and to predict on this basis the future.

E) Goods productions with huge spectrums of product variants use master production scheduling to schedule these product variants.

F) Material requirements planning includes planning of stock-keeping, material transport and set-up times from machines.

G) In goods production, the production programs are created. The available and planned material, machines and human resources are compared in detail for the aim to follow this production programs.

H) Shop floor planning (SFP) in goods production is a common used approach for detailed production planning. Electronic plan tables are used to assign production jobs derived from the orders to machines for manufacturing next steps. A job queue exists for each machine. Ready-for-processing jobs can be assigned to these queues.

However, SFP approaches usually are used in small to medium sized organisations due to rapidly growing problems with planning algorithms when high job volumes are processed.

I) Data collection in goods production is done via PDA techniques (i.e. production data acquisition). Additional hardware is used in goods production to measure machine parameters and production progress by using sensor technology.

Result of this investigation is that neither academic investigations such as IT-Matchmaker nor any vendors offer a version of a PPS system which can be used without adjustments as PDPM system. Although no relevant system has been identified the MPR-II standard has been compared to PDPM in order to identify common features. The results are presented in section 4.2.1.

3.2.3 Scheduling systems

PDPM is concerned with reliable execution of PDP's jobs. Production in time, preventing and handling production errors, and checking system's health are the demands. The appropriate research area, for reliable job handling in time, is job scheduling (JS). The systems, concerned with the described issues, are named JS systems or scheduling systems.

Concepts

According to Sauer, scheduling concepts have to consider problems caused by the chronological assignment of activities to limited resources. Different auxiliary constraints (hard/soft constraints) must be scrutinised, in order to be able to reach the preliminarily defined aims (Sauer, 1997, 13; Smith, 1994, 29-66). Thus, entities of scheduling problems are activities, orders, resources, hard and soft constraints, objective functions and addressed events. Solutions for scheduling problems can be observed in other areas, i.e. operations research and artificial intelligence.

problem approach	predictable	reactive
heuristics	++ (Sauer, 1993)	+ (Henseler & Appelrath, 1992; Henseler, 1995; Sauer, 1993)
optimisation approaches / iterative improvement	+ (Stegmann, 1996)	-
genetic algorithms	+ (Bruns, 1996; Bruns 1997)	-
fuzzy logic	+ (Appelrath et al., 1997, 71-84; Sauer et al., 1997, 145-160; Suelmann, 1996]	+ (Appelrath et al., 1997, 71-84; Sauer et al., 1997, 145-160; Suelmann, 1996)
constraints	+ (Sauer, 1993)	° (Stein, 1996)
neural nets	° (Maertens, 1996; Maertens & Sauer, 1998)	- (Maertens, 1996; Maertens & Sauer, 1998)
multi-agent systems	- (Henseler, 1998)	++ (Henseler, 1998)
++ (strongly applicable); + (applicable); ° (applicable under specific conditions); - (not applicable)		

Table 3.1: Applicability of scheduling algorithms (adapted from Sauer, 2002, 67)

Table 3.1 contains a summary of relevant solutions. These scheduling algorithms and commercial JS systems have been investigated in this research project whether representatives can cover the planning aspect in PDPM or ensure reliable PDP's job execution. The answer is that in principle JS systems can cover certain aspects. However, Brucker defines that some of the easy planning problems are NP-hard. This indicates that algorithms which try to solve these problems can be very time consuming or in some cases unmanageable (e.g. long-lasting) from a practical perspective (Brucker, 2001, 41-48). Thus, characteristics of scheduling are a combinatorial very large search domain, insecure knowledge and a rapidly dynamic problem area (Smith, 1994, 29-66). The complexity

originates from the volume of activities, conditions and objective functions. Insecure knowledge follows due to conflicting values of inexact duration times and imprecise default values from *superior* planning systems (Sauer, 2002, 12-80). Subsequently, to overcome this complexity, the user plays a decisive role. Possible interaction (e.g. substituting an order) can be seen as additional events. Scheduling systems have to support the human planner through visualisation of relevant planning data and integration of knowledge of creation and correction of scheduling plans. A user can plan predictable or reactive. Predictable planning offers possibilities for *new plan* creation, whereas reactively planning includes approaches for re-sorting an existing plan by avoiding many changes.

Enumeration of important scheduling algorithms (cp. table 3.1)

Heuristic methods are based on general heuristic principles such as problem decomposition and heuristic search approaches (Sauer, 1993). Examples are planning algorithms, searching with priority rules or constraint-based searches. Optimisation approaches are linear programming, branch and bound algorithms and iterative methods (Stegmann, 1996). Genetic algorithms start with a population of individuals (plans) and run the steps selection (subset), crossover (new plans) and mutation (changing individuals) until certain criteria are fulfilled (Wang & Zhang & Zheng, 2005, 1157-1163). Threshold Exception or Simulated Annealing (Ganesh & Punniyamoorthy, 2005, 148-154) are contained in those algorithms. Fuzzy-Logic can be used to work with the imprecise knowledge within those systems (Bilkay & Anlagan & Kilic, 2005, 606-619). Constraint approaches are developed to consider certain constraints (constraints satisfaction problem) (Sauer, 1993). Neural nets are used for choosing of activities which need to be planned or for situation assessment (Maertens, 1996; Maertens & Sauer, 1998). In multi-agent systems, agents are used to find an optimal solution in common or try to solve the problems for each individual to find the entire solution (Henseler, 1998) (see section 3.2.7). However, Turner, Mize and Case discuss that for example, in large and real production environments, easy approaches like net plans or priority rules are commonly preferred (Turner & Mize & Case, 1987, 354-355).

The investigation of how JS system or their algorithms can complement PDPM follows in section 4.2.2.

3.2.4 Workflow management systems

The current standard for computerized handling of business processes is WFM. WFM systems include that batch jobs and business processes of workflow-oriented data processing systems can be automated. Additionally, an overview of Petri nets follows. Petri nets are integrated in many WFM systems and are used to describe workflow models in a mathematical correct way.

1. Workflow Management

   Concepts

   „Workflow Management System (WFMS): A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications."

   (Workflow Management Coalition, 1999, 9)
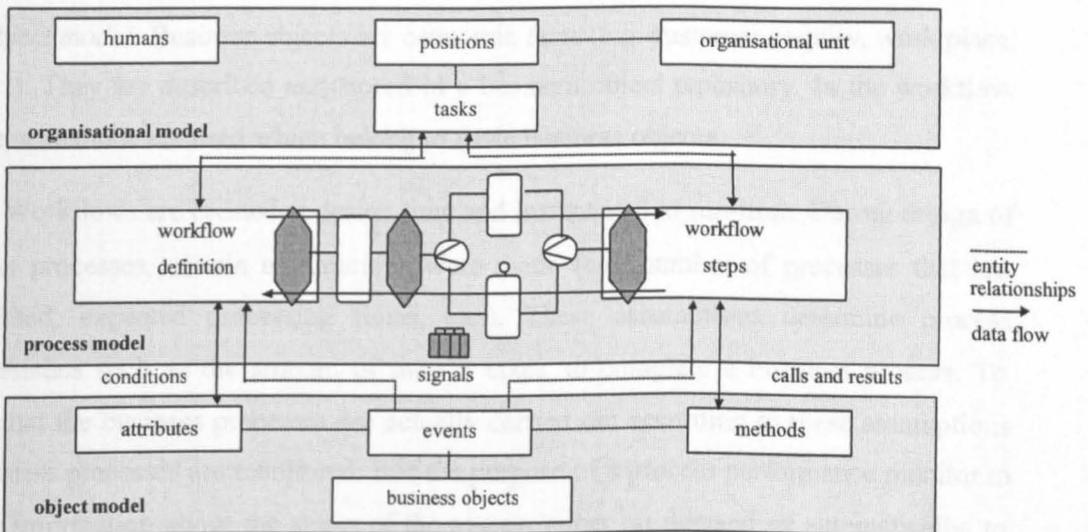
Figure 3.3: WFMS architecture of SAP R/3 (Buck-Emden, 1999; Kurbel, 2003, 342)

The business process in PDP is expressed in the order of production steps to be processed. This chain of production steps is consequently the workflow of PDP. This is why WFM is investigated in the following.

According to Kurbel, WFM can be used as alternative and/or supplement for PPS (Kurbel, 2003, 341-343) and offers in comparison to JS advanced possibilities for controlling and enacting business operations and whole workflows. Business operations can be partly or full automatically controlled with a WFM system. Not only static process-oriented processing is possible, but dynamic enactment of activities is provided. For the dynamic enactment a WFM system supports all involved people and its activities at the appropriate time. For this purpose the definition of activities, the creation of concrete

workflow instances and their execution are included. A so-called workflow engine interprets the activity definitions, interacts with the involved individuals and calls eventually predetermined software tools and applications. For this purpose, in the WFMS-module of SAP R/3, for example, three main models can be divided: the organisational model, the process model and the object model (see figure 3.3). The models are explained in the following:

A. *Organisational model:* All relevant organisation units as for example departments, humans and positions are represented. This is to find assignment of humans to process steps. The workflow definitions refer to this organisational model.

B. *Process model:* In the process model, workflow steps are defined with a workflow definition tool at design time. The workflow steps are assigned to humans of the organisational model. The run-time environment (box 'workflow steps') refer the definition during execution of the workflow instance.

C. *Object model:* Business objects are economic facts (e.g. customer enquiry, work place, etc.). They are described and stored in a business object repository. In the workflow steps methods are used which belong to these business objects.

Workflows are created at design time and instantiated at run-time. During design of business processes, certain assumptions were made (e.g. number of processes that are instantiated, expected processing times, etc.). These assumptions determine process characteristics such as the amount of time it takes to complete a business process. To ensure that the business processes are actually carried out according to these assumptions the business processes are monitored. It is the purpose of a process performance monitor to provide information about the status of the system either on demand or automatically, to issue alerts if exceptional situations occur, and to provide facilities for a process administrator to perform the necessary corrective actions.

During run-time, context (i.e. in form of data) to an activity is passed by using an *input container*. The *output container* covers the results after processing the activity. The data of an output container is then correlated and forwarded to the input container of the next following activity. Thus, sequencing activities with dynamic context is possible.

Production Workflows

In particular, workflows are defined for often recurring or typical business operations of an organisation. Some of the commercial WFM systems support templates for those purposes. In figure 3.4 a categorisation of workflows according to their repetition

can be seen (GIGA Information Group, 2003). The repetition measures how often a particular process is performed in the same manner (Leymann & Roller, 2000, 7-29).

The business value defines the importance of a workflow to the company's business. A process of high business value is at the core of a company's competence. In this research project, we focus on production workflows. According to figure 3.4, production workflows have high business value and are strongly repetitive. They are recommended candidates for WFM systems.
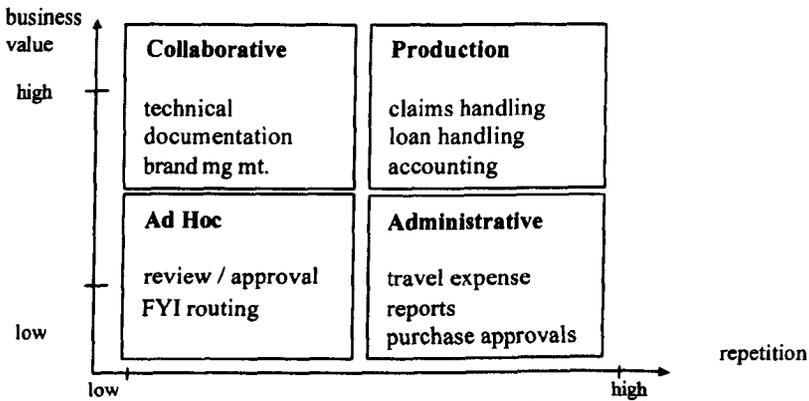
Figure 3.4: Classifying workflow according to business value and repetition (Leymann & Roller, 2000, 10)

2. Petri Nets

In WFM often Petri nets are used (Yang & Lou & Zhou, 2005, 366-371). Petri nets are a universal modelling language with a solid mathematical base (Baumgarten, 1996, 15-21). They are originated from early work of Carl Adam Petri (Petri, 1962). The effective analysis techniques developed for Petri nets and the graphical representation are particularly useful for tracking and diagnostic information. Some research uses, for example, Petri nets to diagnose workflow processes (Verbeek et al., 2001, 246-279; Zandong & Lee, 2005, 735-742), other use Petri net methods for conversation modelling (Cost, et al., 2000, 178-192) and workflow concurrency control (Puustjaervi, 2001, 42-53).
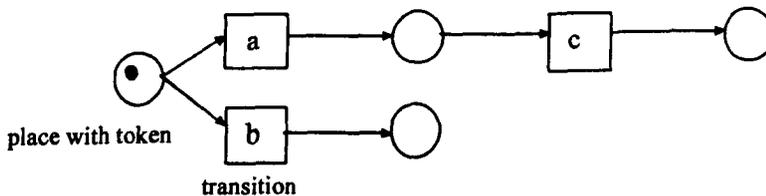
Figure 3.5: Example of a Petri net

The classical Petri net is a directed bipartite graph with two node types called places and transitions (see figure 3.5). The nodes are connected via directed arcs. Connections between two nodes of the same type are not allowed. Places are represented by circles and transitions by rectangles. At any time a place contains zero or more tokens,

drawn as black dots. The state, often referred to as marking, is the distribution of tokens over places. The number of tokens may change during the execution of the net. Transitions are the active components in a Petri net: they change the state of the net according to the following firing rule:

1. A transition 't' is said to be enabled if each input place 'p' of 't' contains at least one token.

2. An enabled transition may fire. If transition 't' fires, then 't' consumes one token from each input place 'p' of 't' and produces one token in each output place 'p' of 't'.

The classical Petri net allows modelling of states, events, conditions, synchronization, parallelism, choice, and iteration. However, the classical Petri net does not allow for the modelling of data and time. To solve these problems, many extensions have been proposed. A Petri net extended with colour to model data, time, and hierarchy structures is called a high-level Petri net (e.g. Jensen, 1987). However, Petri nets describing real processes tend to be complex and extremely large.

Neither WFM systems nor Petri nets have previously been investigated for their appropriateness in PDPM systems. This is why both are investigated in section 4.2.3 for their relevance in this application area.

3.2.5 Exception reporting

Three different interpretations for exception reporting are possible. The first is a technology used for statistical process control named 'control charts'. The second is the computerized reporting of extraordinary events which emerge during the execution of a program. The third interpretation is to concentrate only on the most interesting cases out of a wealth of issues.

1. Control charts (SPC- statistical process control)

In goods production management the production processes are often controlled by using control charts (Shamsuzzaman & Lam & Wu, 2005, 1298-1305). Process data consists of measurements taken to ensure that quality standards or specifications have been met. Normally, there is inherent variability in process data. Proposed first by Shewhart, control charting is a tool used to monitor processes and to assure that they remain stable and under control (Shewhart, 1931). There are many different types of control charts (e.g. x-cards, p-cards, u-cards, etc.) for many different purposes (Rinne & Mittag, 1995).
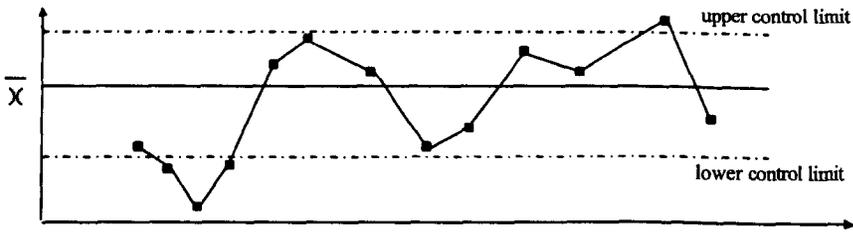
Figure 3.6: Simplified Shewhart control chart (Shewhart, 1931)

In figure 3.6 a process value (x) is monitored. Normally, its expected value is $\overline{x}$. If this process value is within the upper and lower control limits and no particular tendency is noted, the process is referred to as 'to be in control' otherwise it is not.

A goods production has normally some quota of waste (e.g. a poorly fixed borehole). Thus, control charts are an established approach to show and document goods production behaviour.

2. Exception reporting (event handling)

Exception reporting in computer systems is used for the notification of extraordinary events. Results that fall outside a set of predetermined threshold values, or are identified as errors or warnings, have to be monitored and reported. A detailed classification of undesired events in process support systems can be found in (Casati & Cugola, 2001, 251-270). Casati and Cugola describe in this paper the difference between failures (system level failures, process support systems level failures, application-level failures), and exceptions (process-specific and cross-process exceptions, etc.). The complexity for exception handling increases in distributed and component-based environments. For example, in (Klein & Bar-Yam, 2001, 9-12) is describes how sentinel-components can be used to handle emergent dysfunctions during runtime to make open peer-to-peer systems robust and scalable.

3. Exception reporting (information reduction to interesting cases)

"Exception report: report which only gives items which do not fit in the
                      general rule or pattern"
                                              (Ponds-technical dictionary, 2000, 140)

Exception reporting can also be seen as the selection or highlighting of different or critical objects. This is an important issue which has to be discussed in every environment where thousands of objects have to be handled.

Due to the fact that the pure types of exception reporting have not been described in relation to PDPM in the past, all three forms of exception reporting are investigated for their potential application in PDPM systems in section 4.2.4.

3.2.6 Monitoring systems

The concepts of monitoring systems are investigated, as the current state of PDP needs to be recorded, displayed and analysed (e.g. status information is required to inform production operators whether the processing of job X at production step Y is finished in order to be able to start the next production step). This is necessary, as showing previous, current and future production status is desired.

Concepts:

Monitoring is an umbrella term and subsumes the observation of states (observation monitoring), the surveillance of critical objects (detection monitoring) and the comparison between current and planned state (control monitoring). Computerized monitoring can be interpreted as state acquisition of activities or processes by the use of technical facilities. A monitoring system enables intervention in the affected processes if the process performs not as expected (Kurschel, 2000, 66-112; Rackl, 2001, 31-37).

Monitoring techniques:

Two monitoring techniques can be divided: *condition monitoring* and *network monitoring*. Condition monitoring is the supervision of states in technical facilities (Rehorn & Jiang & Orban, 2005, 693 - 710; Yao, 2005, 1379 - 1387). Regularly measurements of meaningful machine states are gathered, compared and diagnosed. For example, sensor technique in combination with data acquisition tools and control charts (see section 3.2.5) are used for automation. In goods production condition monitoring is commonly used. Network monitoring is computerized supervision and regular control of the hardware (e.g. servers), the network (e.g. routers) and related services (e.g. ftp). Commercial representative are for example Hewlett-Packard's Open View (HP Open View Vantage Point, 2000), and IBM's Tivoli Net View (Tivoli Net View, 2002).

There is no related work which discusses condition monitoring and network monitoring in relation to an application in PDPM. Accordingly, in section 4.2.5 this discussion follows.

3.2.7 Multi agent systems

Intelligent software agents are able to complete specified tasks autonomously in a digitalised and networked environment, usually triggered by user requests. The concepts and the research in this area is introduced in this section in order to identify possibilities for PDPM systems.

Concepts

The concepts of multi agent systems can be defined, according to Ferber, as follows (Ferber, 2001, 29-33). A software agent is a virtual entity which can autonomously act in its environment. It can communicate with other agents and is driven by individual intentions. An agent can have own resources and is able to recognise (only to a certain extend) a partial representation of its environment. It has specified capabilities and can offer services. Sometimes, agents are able to reproduce themselves. A multi agent system consists of an environment 'E' and objects 'O'. 'E' is a space which has in general a volume. 'O' is a set of objects where each object is localised in 'E'. Agents can cognise, modify and delete objects. A set of relationships 'R' is defined which connects the objects. Agents are able to execute a set of operations for object receiving, creating, consuming, changing and deleting. Multi agent systems additionally comprise operators which shall present the operation results and the reaction of the environment to the changes.
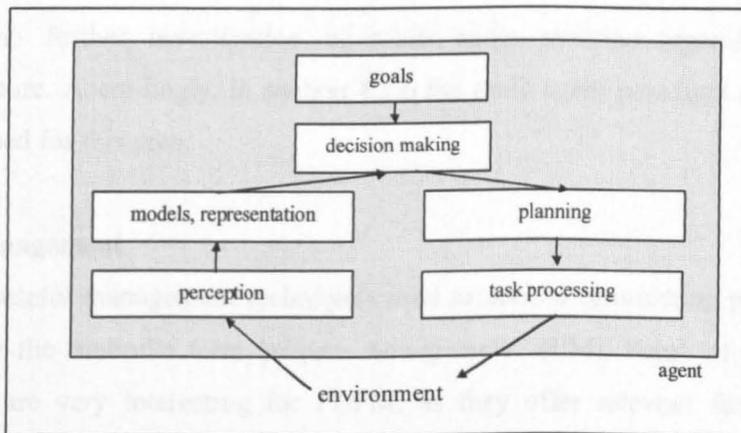
Figure 3.7: Typical agent model with horizontal modular architecture (Ferber, 2001, 149)

Originally developed in the artificial intelligence field, the multi agent paradigm can also be used to model information systems. For example, based on UML (Booch, 1998), Bastos and de Oliveira have introduced a conceptual modelling framework for multi-agent information system design (Bastos & de Oliveira, 2000, 295-308). Agent architectures can be modelled either modular horizontal as illustrated in figure 3.7, or as blackboard, subordination, competitive tasks, production rules, classifier, connectivity, dynamic systems or multi-agent-based. The modelling approach can be functional or object-oriented. Agents can have equal rights or they can be hierarchical subordinated. The linking can be fix, variable or evolutionary, according to the circumstances. Agents can be pre-defined or emergently created. This sketched modelling possibilities enable various application areas.

Application areas

Multi agent systems can be found in various application areas. One of these application areas which is of interest in this thesis is manufacturing. According to Brenner, the main focus in manufacturing is to support planning and controlling goods production processes in PPS systems by using multi agent approaches. The agents perform parts of the PPS tasks as autonomous entities and thus contribute to fulfilling the entire aims in PPS. Disposition on the operational management level as well as process coordination are concrete examples for research projects in this area (Brenner, 1998, 344-347). Enhancements of knowledge-based systems and expert systems in the area of production processes are the preliminary basis of such projects. Trends in this research area are the support of distributed PPS systems, flexible goods production management systems as well as adaptive supply chain management (Reinheimer & Zimmermann, 2002, 76-88; Zimmermann et al., 2002).

There is no further investigation of multi agent systems regarding PDPM mentioned in literature. Accordingly, in section 4.2.6 the multi agent paradigm and related systems are discussed for this area.

3.2.8 Project management

Some very useful management techniques used to control terminating projects are subordinated under the umbrella term *project management*' (PM). Some of these well known techniques are very interesting for PDPM, as they offer relevant functions for controlling timing, costs and resources. The relevant methods are introduced in this section.

Concepts:

According to Turner, Mize and Case a *project* can be described as a major undertaking that is usually not repeated after its completion. Thus, the management of a project should be treated as a one-time job. Turner, Mize and Case explain further on that production management can be a repetitive task in contrast to PM (Turner & Mize & Case, 1987, 353-355).

Projects consist of a set of activities which are linked together in predecessor-successor relationships. An activity has an predicted duration time, estimated costs and assigned resources. For each project it must be defined which activities cannot be started until others have been completed. This depends on the order of events and on available

resources. Time management is scheduling of activities by considering the activity relationships and the resource allocation. One of its aims is to minimise delays.

Clever cost management is to reduce the project costs to a minimum and resource management is concerned with a balanced allocation of available resources. Correcting deviations from the original plan are usually expensive, and participants are thus concerned with accurate activity performing.

Thus, *timing, costs* and *resources* are the main factors to be overviewed in PM. The aims of PM are a high productivity, short throughput times, and optimised and cheap project processes. The achievement of a sufficient economic result is mandatory. Thus, operational as well as tactical and strategic levels of management are involved.

<u>Project overviews</u>
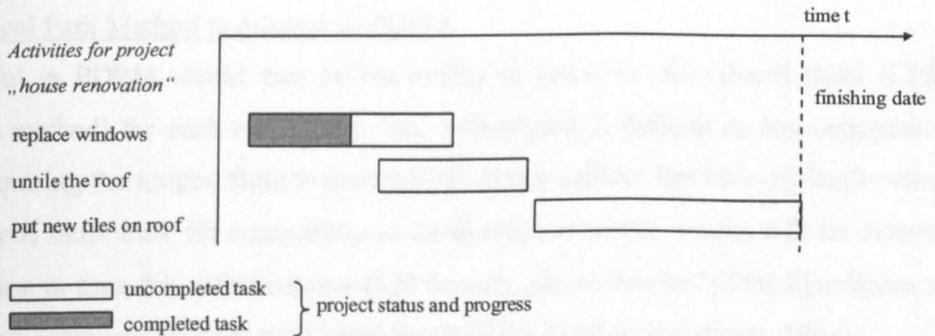
Figure 3.8: Gantt chart

Especially Gantt and Pert charts are valuable overviews and commonly used in time management. Both diagram types complement each other and are an established base for many other overviews, as for example, the due date adherence in a project.

Gantt charts provide graphical representations of scheduling plans. They are of interest for planning, coordinating, tracking specific tasks in a project and are indicating the project progress (see figure 3.8). Activities are planned within the total time span of the project. Each activity is represented by a bar with a specific length. This length represents the activity's duration time.
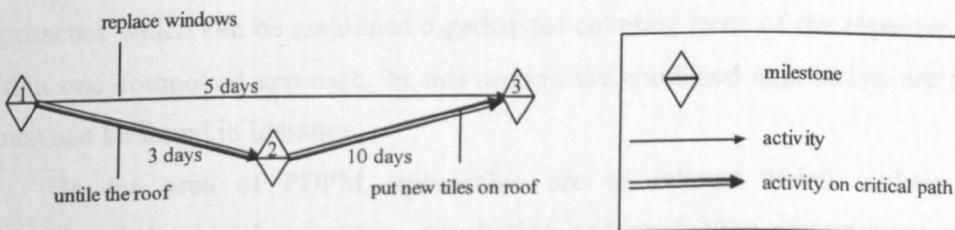
Figure 3.9: Pert diagram

A Pert diagram is a directed acyclic graph. Pert charts illustrate the project as a network diagram and represents thus the predecessor/ successor relationships in addition to scheduling and coordinating activities (see figure 3.9). The arrows in a Pert diagram represent tasks. The allotted time for a task is indicated by vector labelling. With advanced chart versions, it is also possible to identify, for example, buffer-times, minimal and maximal throughput times (Burghardt, 2002, 223-230). Pert diagrams consist also of numbered nodes representing milestones. Milestones represent important events in a project and can be described as activities with no duration time.

However, the problem how data and data packages can be interpreted in terms of PM is not solved in previous literature as it is done for example in Petri nets (cp. section 3.2.4).

Critical Path Method in relation to PDPM

Useful in PDPM would also be the ability to calculate the critical paths (CPM-critical path method) for each end-report. The critical path is defined as that sequence of activities requiring the longest time to accomplish. If any activity lies on a project's critical path and needs more time for completing as expected, the whole project will be delayed. For production in time this information would be very useful. Several CPM-algorithms are available for a systematic critical path identification (e.g. Ford & Fulkerson, 1962).

However, it is neither defined in literature what a project in PDP is, nor is clear how Gantt-Pert- diagrams or a critical path can be characterized in such a dynamic and data-intensive environment. A discussion of PM techniques in relation to PDPM consequently follows in section 4.2.7.

3.3 Combined model approaches – project management systems coupled to workflow management systems

The complex system design concepts for PDPM include a lot of different functionality and properties. The idea in this section is to investigate if there are approaches which can be combined together for covering more of the expected properties within one compound approach. In this section the combined approaches are introduced which can be found in literature.

In the area of PDPM, approaches are of interest which include planning, scheduling, reliable job execution, monitoring and production management overviews. There are a few combined approaches described in literature which veer towards these

interests. Especially a coupling between WFM systems and PM systems is discussed. As Bauer explains it is appealing to link traditional PM systems with WFM systems, because both systems focus on the management of activity chains (Bauer, 2004, 74-86). Additionally, both system types can be combined because of their common focus on control flow management.

In the following discussion, only those approaches are discussed that include both, planning during modelling time and handling of dynamic changes during run-time, because exactly these can contribute in the area of managing PDPs.

<u>Academic work</u>

The theory of interplay between PM systems and WFM systems is described in (Bussler, 1998, 753-758) with respect to how metadata of both system types can be correlated to convert projects in PM systems into workflow instances in WFM systems. According to Bauer, there are two possible types of cooperation between PM systems and WFM systems. First, there is the integration of PM functionality into a WFM system which is called 'closely coupling'. Second, there is the 'loosely coupling' of (already existing) PM systems and WFM systems (Bauer, 2004, 74-86).

A closely coupled integration of PM functionality into the WFM system is described in (Grimm, 1997). Minimal and maximal times between activities at modelling time as well as absolute times for start and ends of activity instances are used to generate a time schedule. Enriched with a Petri net as a common model between both systems and a negotiating intermediate layer, Leung et al. demonstrates how a loosely coupled coordination can bok like (Leung et al., 1995, 859-864). Bauer suggests also to bridge the loosely coupling with a negotiating intermediate layer between both system types to translate project metadata in PM systems into workflow instances in a WFM system. A project in a PM system can then have a higher abstraction level as a workflow instance in the WFM system (Bauer, 2004, 74-86), which is also common in management of PDP.

<u>Commercial representatives</u>

In addition to the above work form academia, there are also some commercial approaches. For example, the WFM system InConcert can be joined with the Microsoft product MS Project (InConcert, 1996). Project Executive works with an interconnection between MS Project and MS Outlook (Project Executive, 2002). The task list in MS Outlook is used to start process steps. Through sending specialised e-mails, operators and project manager inform each other about the progress of the project Thus, management

information can be up to date. Another approach is SpeeDEV (SpeeDEV, 2004), a software development environment with included workflow and PM functions.

However, none of the introduced combined model approaches are previously discussed in relation to PDPM. Consequently, this discussion is provided in section 4.3.

3.4   Chapter summary

In this chapter, available approaches within information system practice are introduced which could be of interest for computerizing PDPM. For providing an overview of available literature approaches in section 3.2, first a taxonomy of relevant areas of interest is offered, for a better orientation. Reasons for excluding or including approaches in the investigations are described. The examination is concentrated on management approaches such as goods production management, data processing management, and general management techniques. Executive approaches for conducting PDP itself are excluded from the discussion. This is namely the research of distributed systems, component-based systems, data warehousing concepts, data mining and data quality approaches.

The relevant single model approaches found in literature are discussed in detail. The main focus for this investigation is the management of timing in case of PDP:

Production planning systems (PPS systems): PPS systems are used for goods production and often use the MRPII concepts.

Job scheduling systems (JS systems): The reliable execution of data processing jobs is the strength of JS systems. Jobs can be scheduled due to different requirements.

Workflow management systems (WFM systems): The definition and the enactment of workflows is the focus of WFM systems. Workflows can consist of manual tasks as well as of data processing jobs.

Petri nets approaches: Petri nets which often complement WFM concepts offer life-cycle management possibilities.

Exception reporting: Three methods of exception reporting can be distinguished. Control charts are primarily used in goods production for quality control. Another form of exception reporting is event handling which is useful to prevent production errors and to reduce reaction times. Exception reporting while concentrating only on interesting issues is a good approach in environments with high data volumes.

Monitoring systems: Two types of monitoring systems are available. Condition monitoring is used in goods production to acquire data from production machines.

Network monitoring offers possibilities to control the network and hardware layer of IT-systems.

Multi agent systems: The multi agent paradigm offers great modelling possibilities for various application areas. The review in literature has shown that, parts of PPS systems can be modelled and programmed using this paradigm, or that Petri nets can be developed as multi agents.

Project management approaches (PM): PM projects have usually a single-job character. The aim is to control timing, costs and resources. Concepts for project overviews are Gantt-, Pert- and critical path diagrams. Milestones, predecessor- and successor relationships between activities can be graphically displayed. Time management of due dates, buffer times and delays is established in industry and easy to understand for participants.

Combined approaches found in literature are examined in section 3.3. Primarily the discussion of a coupling between PM tools and WFM approaches is previously described. A coupling can be seen as appealing idea for fulfilling several PDPM functionality as compound approach.

Chapter 4

Discussion of the literature review in relation to periodic data production management

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Chapter objective

> *None of the research approaches introduced in the last chapter has previously been investigated in relation to the area of IT-aided periodic data production management. This investigation is contributed and described in this chapter. The existing management methods are investigated in respect of how well they meet the demands of planning, monitoring and controlling periodic data production. The possibilities of using any of these proven management techniques (which may need to be adjusted or adapted) are also explored.*
>
> *However, after this study it is clear that there is still no approach which fulfils all the requirements of an adequate application in this area. Based on these findings key research issues are discussed and research scopes for new research are reasoned.*

Chapter contents

4 Discussion of the literature review in relation to periodic data production management

4.1 Introduction

This chapter provides the discussion of the identified available approaches (see chapter 3) concerning IT-aided PDPM. Section 4.2 investigates the identified single model approaches. They are critically reviewed and it is determined how these approaches affect system design concepts for meaningful PDPM applications. The same discussion follows in section 4.3 for the identified combined model approaches as planning, monitoring and controlling PDP comprises multifarious features. Due to the outcome of these discussions, that neither the single model approaches nor the combined model approaches deliver adequate system design concepts, in section 4.4 the issues of PDPM that are not covered in the literature are provided. The limitations of the currently available approaches are summarised and the present problems with establishing sophisticated PDPM are specified. In section 4.5 the research issues which have been defined at the beginning for this research project are discussed regarding the results which have been gained so far.

4.2 Discussion of the single model approaches

As relevant single model approaches for PDPM system design concepts have been defined the following. In section 4.2.1 PPS systems are compared to adequate PDPM systems. Common features are identified. Section 4.2.2 investigates how JS systems or any of the related scheduling algorithms can complement IT-aided PDPM. WFM systems and Petri nets and their relation to PDPM systems are discussed in section 4.2.3. Section 4.2.4 examines whether exception reporting approaches are relevant in this field. The discussion regarding the applicability of monitoring systems is presented in section 4.2.5. Possibilities of the multi agent paradigm or related systems are examined in section 4.2.6. Finally, PM techniques are investigated in relation to PDPM systems (see section 4.2.7).

4.2.1 Production planning systems

In order to identify the similarities, the following comparison between data and goods production management after MRP-II has been published in (Schanzenberger & Lawrence, 2005, 203-217). All descriptions about the functions in goods production in this comparison are according to Kurbel (Kurbel, 2003, 110-112). The comparison to PDP only

is added by the author. Each doted line in figure 4.1 indicates the affinity between functions in goods production and PDP.
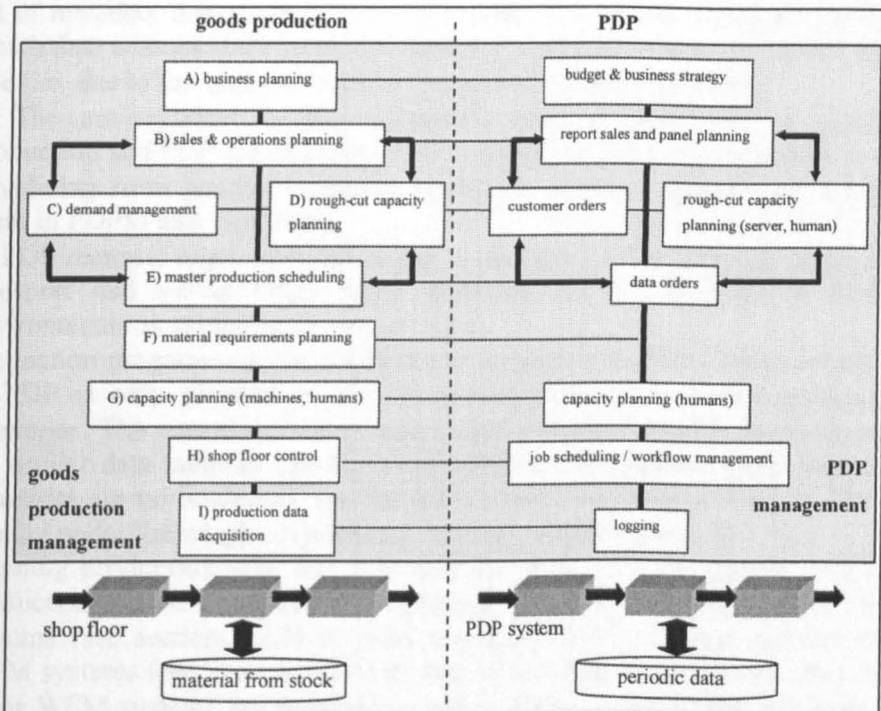
Figure 4.1: MPR-II for goods production management compared with PDPM
(Schanzenberger & Lawrence, 2005, 208)

A) The aims of business and budget planning are increasing productivity and a costs-aware production, for contributing to business success. These aims are equal in goods production management and PDPM (cp. section 2.2.4). Thus, many of the key performance indicators used in goods production for evaluating these aims need only to be interpreted in PDPM (see section 2.3.4).

B) In comparison to goods production management, sales and operation planning in PDPM differs, as reports can be sold multiple times without processing more source material. In PDP the long-term sales and operation planning can be interpreted as arranging report quantities, and report theme identification. The technical term is to plan a so-called panel (see appendix B).

C) The financial departments in both production types use the same methods for predicting sales volumes and customer order quantities. The same key performance indicators can thus be used in goods production management and PDPM (see section 2.3.4).

D) The rough-cut capacity planning of manpower can be seen as equal in both production types. However, in PDP only human manpower limits the production as server resources are cheap and replaceable. Server quantities are thus only very roughly estimated and usually a plentifully reserve can be added to guarantee processing of peak loads.

E) Goods productions use master production scheduling in order to schedule product variants. The end-reports in PDP differ in content but not in their structure due to the repetition in each production period, and thus product

variants need not to be considered. For this reason, this point can hardly be compared in both production types.

However, in PDP so-called data orders are scheduled. A data order is a set of metadata derived from the end-product *report* and includes roughly which data sources shall be used to finish a report and when the reports are due (i.e. due to the many deviations changes are always possible).

The consequence is, the techniques used in this area in goods production and PDP are different. Accordingly, tools for master production scheduling from goods production cannot be used or adjusted for using them in PDPM and vice versa.

F) In PDP material requirement planning is obsolete. Stock-keeping, material transport and set-up times from machines are not relevant in PDP environments as explained in section 2.2.2.

G) Production programs can be identified as negligible in PDP. Data material in PDP is only planned at the production entrance to ensure punctual deliveries. The reason is, late or missed deliveries can usually be replaced by similar data material due to the principle of the statistic truth. Server quantities are no bottleneck and human resource planning is done in PDP usually under the rough-cut planning level explained in point D).

H) Planning production jobs for each machine with SFP systems in goods production can be compared with planning jobs for each server with JS systems (see section 3.2.3) or with planning each workflow activity in WFM systems (see section 3.2.4) in data processing management. Jobs in JS or WFM systems are assigned to server farms, released and executed. User interactions for finishing production steps are usually supported in tools from these areas.

PDPM has in this point more similarity to data processing management than to goods production management. Thus, job scheduling on this level needs to be investigated in the areas of JS or WFM (see section 4.2.2; section 4.2.3).

I) Logging protocols in PDP substitutes complex production data acquisition in goods production. Neither additional hardware nor sensor technology is necessary in PDP. Production steps in PDP are themselves programs and can thus log easily their status.

(Schanzenberger & Lawrence, 2005, 203-217)

Summarizing these investigations, it is possible to interpret the key performance indicators of goods production for the management in PDP, as the business goals of both production types do not differ. This interpretation is useful because the original key performance indicators are proven and established (cp. section 2.3.4).

However, conducting, planning, and monitoring production are different tasks in both production types. An application in PDPM by using PPS and SFP representatives may thus not justify the needed adjustments at these tools. Approaches for planning and monitoring data processing systems seem to deliver in this case more promising methods and are for this reason investigated in the following sections. However, from the research and the industry experience in this area can clearly be learned how PDP needs to be

managed because goods production and PDP comprise a lot of common activities and the same business goals.

4.2.2 Scheduling systems

Computerized PDP needs a scheduling environment where programs are called automatically (and/or manually) with variable input and output parameters. In such environments system health information needs to be provided and problems must be forwarded to the staff. JS systems are the relevant approaches.

However, in today's commercial representatives (e.g. UC4, 2003; CA-Computer Associates International Inc., 2003, etc.) planning is not supported as necessary for PDP. One reason is that JS systems support control flow management but do not support data flow management which is crucial important in PDP (i.e. a JS system executes a job which transfers input into output data packages but does not care about which data packages it processes). Jobs can be scheduled to specific times on particular servers and the control flow of jobs can be sequenced, but planning in production entails more. Sequencing in PDP means, the dependencies between the data package contents are needed for knowing which job can follow on a previous one. To track the data flow of past, current and future production is not possible. This means that a production operator has no chance to track which data sources or intermediate data packages have been used to create a report (i.e. no evidence of which data is included in a report), and it does not matter if this enquiry is concerned with a past, the current or a future production cycle. In addition to the lack of production planning, JS concepts usually lack strong management overviews, except analysis of delayed jobs. PDPM is thus beyond the scope of JS, as JS only means to execute PDP. Neither strategic nor tactical management is provided, nor operational management is sufficiently supported today. The fear in operational management is that, automated planning and re-planning of tens of thousands jobs, as expected in PDP (cp example in section 1.2.1), might still remain a manual task to a certain part, due to the complexity with scheduling algorithms.

However, the result of this investigation in relation to PDPM is, scheduling systems can be recommended for a layer in the system design concept where reliable job execution is provided, but a complete concept needs other layers above for data flow control and PDP overviews. Choosing a scheduling algorithm or any commercial representative for this system layer depends strongly on the specific requirements for such an application and can vary in different cases. For example, in environments where extensive re-planning is

necessary a scheduling algorithm may be preferred which meets this demand, but it may not be suitable in other environments.

4.2.3   Workflow management systems

WFM as well as Petri nets, are of interest when discussing PDPM. However, the thorough investigation shows both techniques have shortcomings in this application area.

1.   Investigation of WFM systems

Unfortunately, WFM systems lack some important concepts for adequate planning, monitoring and controlling in the case of PDPM:

Planning: Excessive planning and re-planning is not only a problem in JS (see section 3.2.3), but also in WFM as the problems with high-performance planning algorithms remain. Research for planning methods in WFM is a young discipline and thus not sufficiently solved in today's commercial representatives. Early research in this area is, for example, a theoretical description how metadata of project management can be correlated to scheduled workflow instances (Bussler, 1998, 753-758). Another approach describes integrated workflow planning and is introduced in (Schuschel & Weske, 2003, 771-781). Special in this approach is that both planning and coordination are supported during run-time in order to avoid performance and consistency problems. Automated re-planning is added by adopting new process definitions during process execution. However, no experience is published in relation to PDP where thousands of jobs must be planned.

A further critic of WFM in relation to PDPM is that the processes are only planned and monitored without using this information for optimisation. In the workflow theories exist no back coupling of the monitored information to optimise the process in the next production period. The repetitive character of PDP is not optimally addressed. This is also observable as the creation of workflow definitions and instantiation is still a manual effort.

Monitoring: WFM systems manage sufficiently the control flow and do adequately document all processing states. However, the data flow is not satisfactorily visualised and is not the focus in this area. For PDPM this is not acceptable, as one of the main requirements is to be able to track the transitions between data packages (cp. section 2.2.4, point C). Theoretically, input and output container can be used to process and forward the data packages correctly, but an adequate overview of

previous, current and the future data flow is not offered, today. The changing product keys of data and data packages cannot be tracked or queried accordingly and are thus not addressed.

Controlling: Let us assume planning and re-planning would be possible. However, in this case the process definitions must be updated very often due to the many run-time deviations. This is a manual task in WFM systems, and would need plenty of manpower for thousands of jobs a day, as expected in PDP.

Moreover, it is not sufficient to estimate the processing times of production jobs only during design-time. In PDP the processing times are strongly related to the different data packages and their current content. The content can vary in different production periods (e.g. in market research a different production volume is expected during a Christmas period). Furthermore, the reliability of manual processing time estimations can vary. For the huge number of expected production jobs (cp example in section 1.2.1) it may be more advisable to avoid such continuing estimations. A problem solution would be to log the processing times of jobs and to automatically use these measurements in the next production periods as pre-settings. The repetitive character of PDP would then be optimally used.

Another lack is that the available key performance indicators cannot be unambiguously drilled down to the data packages, as the overview of the data flow is not advanced. Sophisticated reporting in form of key performance indicators can thus be inefficient and non provable in the case of PDPM.

This investigation has shown that the requirements of PDPM as, for example, to cope with changing product identifiers and the many deviations, are not addressed by workflow related approaches. The main focus in this research area lies still on modelling and instancing business processes, not on planning repetitive production or using any advantages given through the possibilities/risks of data aggregation. In addition, the distributed environments which are usual in PDP often are not adequately considered in commercial representatives.

2. Investigation of Petri Nets

In relation to PDPM it can be summarized that, it would theoretical be possible with Petri nets to develop a tool for lifecycle management (see appendix A). However, the question whether this is practicable for thousands of jobs, which need to be modelled with high-level Petri nets to include data, is unanswered. In previous research it is not

investigated whether such approaches are able to cope with highly dynamic and large PDPs. The complexity, the expected workload, the unsolved problems with assigning new and intermediate data packages to new colours, and the handling of run-time deviations, are raising doubts.

Previous, current and future data flows would need to be monitored, but Petri nets are only able to show a current snapshot. A token in Petri nets cannot be divided into several parts nor can several token be merged. The changing identification keys of data packages are thus not addressed.

Finally, the scope in PDPM includes more than only lifecycle-management. Petri nets can just be seen as an abstract basic level for production overviews. However, as Petri nets are often used in simulations, it might be worthwhile researching in the future whether they can be used in PDPM for simulating future work loads without slowing down production during run-time.

4.2.4 Exception reporting

The results of investigating exception reporting techniques in relation to PDPM are the following:

1. Control charts (SPC- statistical process control)

Control charts are an established approach to show and document goods production behaviour (e.g. identification of the quota of waste). In PDP, very little waste is produced as data is stored before execution and processing can usually be repeated in case of program crashes. Control charts in PDP are thus only interesting for data quality issues. Data quality is, for example, interested in approaches for data cleaning (Galhardas et al, 2001). However, in order to limit the scope of this thesis in section 1.3.1 is stated that data quality is not considered in this research project.

2. Exception reporting (event handling)

There is clearly a need in PDPM for interdisciplinary event handling between PDP components, due to each production step is a program and can raise events. In analogy to handling asynchronously events in object-oriented programming environments as for example provided in (Menon, et al., 1993, 383-390), exception reporting can be generalised for a complete event handling in PDP systems. The purpose of event handling is to shorten slack times and downtimes effectively, as well as to support smooth operation of the production processes.

3. Exception reporting (information reduction to interesting cases)

As in all environments with high data volumes it can be recommended to provide PDPM overviews which focus only on relevant cases. For example, production delays, because of job processing or delayed/omitted source data deliveries, are relevant issues. In contrast, production jobs without problems are sometimes queried, but they need otherwise no special attention anymore. Good practice is thus to reduce particular management information by concentrating on problem, unsolved or interesting cases. The result is problem detection is optimised, reaction time and workload can be reduced.

4.2.5 Monitoring systems

Condition monitoring is an approach common in goods production. The equivalent technique in PDP is data logging. Condition monitoring is not a suitable technique that can be used for data logging and needs thus no further attention.

In contrast, network monitoring can complement PDPM on the hardware and network layer. The computerized supervision and regular control of the hardware (e.g. production servers), the networks (e.g. router) and services (e.g. ftp) is of interest. Commercial program representatives are for example Hewlett-Packard's Open View (HP Open View Vantage Point, 2000), and IBM's Tivoli Net View (Tivoli Net View, 2002). However, these tools only offer computerized supervision of PDP on this low level. PDPM is far beyond the scope of network monitoring and needs thus further investigations.

4.2.6 Multi agent systems

Some of the PPS systems are implemented as multi agent systems. However, as explained in section 4.2.1 PPS approaches are too dissimilar in relation to PDPM. This is the reason why PPS approaches developed as multi agent systems do not particularly change this situation.

According to Ferber, Petri nets can be implemented as multi agent systems (Ferber, 2001, 195-202). As discussed in section 4.2.3 Petri nets are well-established for enabling life-cycle-management in parallel processes. However, PDPM is beyond the scope of life-cycle management for data package as this would only mean a representation of the current production state and querying past or future production cycles would not be supported. Accordingly, this might be only a possible part of a PDPM system.

As no multi agent system especially provided for the management of PDP is available the multi agent area can only be seen as a possible family of development

technologies for PDPM systems. In this research project an initial system design concept based on the multi agent paradigm as been investigated but was rejected in favour of more promising concepts (see appendix A).

4.2.7 Project management

Due to its periodic nature PDP is clearly not a terminating project as expected in PM. Accordingly, traditional PM approaches cannot easily be mapped to PDPM. However, projects are similar to PDP and Gantt-, Pert- and critical path- charts as provided in PM are of high interest as they offer schedules and show predecessor and successor relationships between activities. These methods would also be effective for tracking data packages in PDP. In particular, the definition of milestones would be advantageous in PDPM . They could be interpreted as the events of finishing a production step. However, the problem how data and data packages can be interpreted in terms of PM is not solved in previous research as it is done for example in case of Petri nets (see section 3.2.4).

Traditional PM thus delivers a lot of attractive ideas, but no approaches in this direction are previously researched, or are available as commercial representatives for PDPM.

4.3 Discussion of the combined model approaches

The most similar combined model approaches in relation to PDPM which are published in literature are a coupling between PM and WFM systems (cp. Bauer, 2004, 74-86). However, no experiences are published about the strength of the combined model approaches in order to cope with the large amount of data and the many normal deviations within industrial-strength PDP. Nor are investigations described whether the creation of workflow definitions and instantiation can be automated in a repetitive environment. The problem of the data package's changing product keys is not addressed as originally these approaches have not been designed for PDP. The problem of mapping a sequence of the production status used in the PM application unambiguously to the workflow instances remains. If, for example, one data input of any given period is missing and it was decided to replace it with the same data input from the previous period, then the project in the previous period determines the current period. This behaviour leads to cyclic project sequences which are unmanageable, incorrect and unserviceable.

The available commercial approaches in this area do not considerably change this situation. InConcert is not suitable for PDPM because it does not support automatic recognition of dynamic changes during run-time, and thus no actual due dates can be

compared on-the-fly with the project plan, (InConcert, 1996). Project Executive seems not to work, as the sheer amount of data and processes outgrows the limits of the both integrated systems (Project Executive, 2002). Moreover, the problem of coordination in a distributed environment is not sufficiently addressed. Additionally, PDP has process steps which are fully automated and other steps which must be manually completed. If a task has to be processed manually, it is also possible that it might not be finished without interruptions (e.g. waiting for information guaranteeing data quality) and may be finished by different operators. These problems are also not discussed in this concept. Last but not least, SpeeDev is only relevant for the area of software development (SpeeDEV, 2004).

Finally, none of the introduced combined approaches in literature has been previously investigated for the management of PDP. None of them has been tested or prototyped in such an environment. However, the ideas to couple anyhow PM techniques with workflow or job execution methods is appealing and is investigated in more detail in this thesis for the special case of PDPM (see chapter 5).

4.4 Issues in periodic data production management that are not covered in literature

As described in the previous sections of this chapter, research and approaches which can be found in literature do not cover satisfyingly PDPM. Some features can be addressed, some others not. However, there exist no state of the art and no off-the-shelf product which can be used for building a whole PDPM system. In this section the present problems which can be identified for PDPM are summarised.

The major problem identified in the literature might be that management approaches are either very specialised to deal with goods production or very closely related to data processing systems. An adaptable solution for the management of the synthesis of both system types has not been satisfactorily investigated in previous research However, as discussed in this chapter, the following aspects can be used in a system design concept for PDPM:

- Key performance indicators from goods production can be interpreted for the PDP environment.

- Scheduling algorithms and JS systems are able to provide reliable job execution in PDP.

- Network monitoring systems can complement system reliability and ensure high-availability.

- Exception reporting in form of event handling and focusing on interesting cases can be used to proactive inform about production issues and to reduce management information.

The remaining issues which have not sufficiently been addressed in the proposed management approaches described in literature are the following:

1. Problems arising due to coping with PDP specifics

- None of the literature approaches was able to deal sufficiently with the changing product identifiers of data and data packages.

- The question remains, how to drill down the key performance indicators unambiguously to the data packages. And the other way round, calculation rules for key performance indicators are not established in this business case.

- Production overviews for PDP are not established. It is not known how production overviews should look like, or which are effective.

2. The difficult observation of the data flow

- In PDP it is much more required to track the data flow instead of the control flow. A control flow is available in form of a workflow, but more important is to overview the flow of the data packages. The difficulty might be that tracking the data flow is much harder than control flow management.

- The management approaches described in literature are lacking possibilities for querying the data flow of past, current and future production. However, a comparison of several production periods would add value into the discussion about productivity.

- The problem of mapping a sequence of the production status unambiguously to the workflow instances remains.

- The dependencies between the data packages are needed for knowing which job can follow on a previous one. Due to the aggregations and separations, and the changing product keys of data and data packages, this is difficult to track.

3. Planning problems

- Both deviation types, deviations that arise due to dynamic time scheduling and deviations that arise due to changing input data, remain problematic. Especially, the expected high volume and thus the high dynamic in production is difficult to

overcome. Both need to be treated during run-time as they are often unknown during prior planning phases.

- The risk is to come across the limit of scheduling algorithms, because of the high job volumes and the numerous dynamic deviations that arise due to dynamic job scheduling. Due to these limits, planning seems to partly remain a manual effort.

- The replacement of input data in current periods with data input from previous periods leads to cyclic project sequences which are undesirable, incorrect and unserviceable.

4. Ignoring the repetitive character in PDP

- Most approaches described in literature lack a back coupling of the monitored information to optimise the process in the next production periods.

- The investigation has shown that assumptions of processing times are usually not considered or not logged. Processing time logs are not used as pre-settings in the next production periods.

- Suitable management approaches need to have a high automation level. If not provided, then the high data volumes in PDP can neither sufficiently be overviewed nor managed. High automation is also required for relieving individuals from administrative tasks.

- In most literature approaches workflow definition and instantiation would still be a manual task.

5. Difficulties with this distributed environments

- PDP is an environment where jobs can be parallel processed. The process coordination can thus become difficult in such environments. The right data packages need to be in due time on the right place, not to delay production.

- Distributed environments are hard to manage due to the different local needs of the distributed components.

- Distributed environments need a strong management of the interplay between the local parts.

- Literature approaches predict a high communication effort in decentralised environments. The risk is that this could become unmanageable at peak-times.

4.5   Discussion of the research issues

In this section the research issues introduced in section 1.3.3 of this research project, are discussed in relation to the literature review provided in this chapter. The study of the literature review leads to the following insights regarding the research issues:

Issue1:   What are the requirements for PDPM and what properties are critically important for a successful PDPM?

PDPM includes a lot of different functionalities. These functionalities have not been clearly defined in relation to PDPM in previous research. There are no academic or commercial systems especially designed for PDPM. Thus, the critically important requirements and properties of PDPM needed to be identified in this research project prior to designing appropriate system concepts (cp. chapter 2).

Issue2:   What possible system design alternatives are there for satisfying the identified critical PDPM properties and are the various strategies particularly relevant for specific scenarios?

Possible design ideas for PDPM concepts can be found in the research areas of traditional production management and data processing management as PDPM is a synthesis of both management types. However, approaches in these areas offer only minor parts of the proposed PDPM system because PDPM also differs from the other management types. Thus, the strategies found in literature are more useful in scenarios for computerized supervision of very static (i.e. not dynamic) PDP systems. Those static systems can for example be systems without emerging deviations, with less planning effort, where data flow dependencies are not relevant, or in non-repetitive environments.

Issue3:   How can new system design concepts for PDPM best be evaluated, in practical terms, and what are the most effective criteria for evaluation?

Traditional approaches for MIS evaluation are the creation of cost-benefit analyses, user interviews or performance measurements. Criteria which can be derived from these approaches are quantifiable tangible benefits as for example a return on investment, user friendliness and performance measurements. However, the value of system design concepts is usually higher than the value of implemented MIS as appropriate concepts enable sophisticated tools in the first place. Moreover, PDPM systems support management decisions and incorporate also non-quantifiable

intangible benefits as for example the improvement of the PDP process quality. Therefore, in this thesis will be investigated if switching to scenario-based evaluation techniques where achievable benefits themselves can be identified and equally tangible and intangible benefits can be considered, is a viable approach for evaluating proposed system design concepts.

From the so far provided literature review and its discussion can be discovered that it is advantageous to learn from the management approaches of traditional production and of data processing for the application area of PDPM systems, because of the similarities between these approaches and PDPM. This is effective as the features of available approaches are usually proven and established. This qualifies some approaches as metaphor models.

Issue4: To what extent is prototyping all or part of proposed new system design concepts and tools a viable approach to testing and evaluation?

Prototyping is a commonly used approach for identifying dead ends and appropriate features of information systems. This is the reason why this approach will be investigated in this research project for its effectiveness in relation to testing and evaluating the implementations of PDPM system design concepts. A prototype will be introduced that is based on a system design concept which is proposed in this thesis. This will contribute experience in relation to this research issue.

The over-all result is research into PDPM systems and their system design concepts is useful as there is no sophisticated academic or commercial system which covers all required functionalities in this case and a need in industry has been identified.

4.6   Chapter summary

The relevance of the introduced approaches (see chapter 3) in relation to PDPM is discussed in this chapter. The results of investigating the single model approaches can be summarised as follows (see section 4.2):

Production planning systems (PPS systems): Conducting planning, monitoring and controlling in goods production is different from PDPM. This leads to the conclusion that PDPM cannot use or adjust PPS systems for a real-world application. The result is, only the business goals of both production types are the same. Consequently, it is of interest to interpret the key performance indicators used in goods production for PDPM.

Job scheduling systems (JS systems): The concepts of JS systems can be used to fulfil a system architectural layer in PDPM where reliable job execution is required. The strong affinity of PDP to data processing concepts enables this possibility. However, scheduling algorithms for job handling in time have limits when high job volumes need to be planned during run-time and if re-planning is expected due to numerous deviations during run-time.

Workflow management systems (WFM systems): The need for excessive planning and re-planning is not only a problem in JS systems, but also in WFM systems. Research for planning methods in WFM is not completed today. Furthermore, the focus in research for these systems lies still on workflow definition and enactment and not on supporting PDP environments. Finally, there are still open research questions regarding distributed WFM.

Petri nets approaches: Petri nets which often complement WFM concepts only offer life-cycle management possibilities and lack further management approaches. They can thus be only seen as basic ideas.

Exception reporting: Control charts can be used in PDP for controlling data quality issues but do accordingly not meet this research scope. Event handling is useful in PDP to prevent production errors and to reduce reaction times. Exception reporting by concentrating only on interesting objects will be a good practice in PDPM as reducing management information to relevant cases can ease the handling for users.

Monitoring systems: The investigation of monitoring systems shows that first and foremost network monitoring systems can complement reliable job execution. Logging of PDP status needs no further examination as PDP is easily able to log protocols by itself because of its process-oriented character.

Multi agent systems: Unfortunately, there is no special approach published that supports especially the mechanisms needed in PDPM. Multi agent systems can thus be seen as technique which could enable developments for PDPM.

Project management approaches (PM): PM cannot easily be mapped to the periodic character of PDP. Although the concepts for project overviews are of interest, PM can consequently only be seen as collection of ideas what may be possible for PDPM.

The combined approaches which have been found in literature are examined regarding PDPM in section 4.3. However, as PM and WFM concepts do not sufficiently support PDPM requirements as previously explained, these concepts do not contribute further approaches.

In section 4.4 the determined present problems for establishing sound PDPM are summarised. All the presented issues are not covered in literature. The problems can be related to the specifics of PDP as, for example, the changing product keys of data and data packages. It is furthermore difficult to track the data flow instead of the control flow. The large amount of dynamic data and the numerous deviations during run-time additionally complicate PDPM. The planning procedure in repetitive data-intensive environments is not sufficiently investigated in existing research. The advantages of the repetitive character in PDP are not adequately used. Finally, to establish sophisticated IT-aided supervision in distributed environments is difficult, due to a usually high communication effort and the coordination problem of a sound interplay of all production components.

In section 4.5 the research results presented so far are discussed in relation to the research issues of this research project (cp. section 1.3.3). Summarised the results show that the research of PDPM systems and appropriate system design concepts is useful as there are no specialised approaches for PDPM today.

Chapter 5

Theoretical research – discussion of approaches for periodic data production management

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Chapter objective

> *Various sophisticated ideas for system design concepts have been investigated. However, the most interesting concepts have been found by underlying established and strong management approaches identified in literature as metaphor models. Using these metaphors, sophisticated system design concepts specialised for periodic data production management, have been derived.*
>
> *The aim in this chapter is to discuss the promising system conceptual ideas. These candidate approaches are then compared to add value to this discussion. Furthermore, for each approach the introduced present problems of periodic data production management are discussed.*

Chapter contents

5 Theoretical research – discussion of approaches for periodic data production management

5.1 Introduction

The system design concepts for PDPM systems, which have been studied during this research project, are described in detail in this chapter. These concepts are comprehensive abstract models for this type of decision support system. This is in order to gain a common knowledge base for system design in case of computerised PDPM.

The analysis of PDPM accomplished during this research project has enabled a profound discussion of possible system design concepts. This discussion is presented in section 5.2 and establishes sophisticated decision support for system designers. The proposed approaches are subsequently compared. The comparison of approaches particularly assists to identify effective system concepts for supporting different business goals. Section 5.3 emphasises the generic problems that are solved by using the proposed approaches.

5.2 System design concepts for periodic data production management

For all approaches the same underlying and distributed PDP system is assumed in order to guarantee equal pre-conditions. Only the PDPM systems which are proposed to manage PDP differ. At the beginning, there was consideration of some initial PDPM proposals. These proposals have been rejected for prototyping, but the discussion of them have led to other more advanced concepts and are accordingly introduced in appendix A. As all approaches are based on metaphors known from literature, the aim in this section is to provide a brief overview of them by describing their relation to these metaphors. This is presented because the metaphor models indicate roughly the fundament of an approach. A detailed description of each approach follows subsequently in the sub-sections. The advantages and disadvantages of the approaches are described by comparing them to the previously identified problems in PDPM (see section 4.4).

The following enumerations of the approaches which have been evaluated as possible candidates for prototyping are presented for providing an overview (see table 5.1):

- *Closely coupled approach:* The metaphor model used for the closely coupled approach is PPS. This approach supports a high potential for production optimisation by creating production plans.

- *Loosely coupled approach:* The loosely coupled approach is based on traditional PM techniques. This concept is of interest because unhindered job execution without adapting legacy components is offered by automated milestone scheduling.

metaphor model proposed PDPM approach	PPS (section 3.2.2)	PM (section 3.2.8)
X: PDPM approach uses this metaphor model		
relevant candidate approaches		
closely coupled approach	X	
loosely coupled approach		X

Table 5.1: Metaphor models used in the candidate approaches for PDPM

The common concepts of the both candidate approaches are explained in section 5.2.1. This includes the explanation of the applied naming convention and the basic identical functionalities which both approaches incorporate in order to increase comparability.

In section 5.2.2 the closely coupled approach is explained in detail. Its details are discussed with one high-level and one detailed multi-layered system design concept. The high-level concept provides overview of the used communication coupling method. The detailed concept is used to describe the manifold functionalities of this approach

Section 5.2.3 is a detailed description of the loosely coupled approach. Similar to the description of the closely coupled approach, one high-level and one detailed multi-layered system design concept is provided. The high-level concept explains the communication coupling in this approach. All PDPM functionalities are explained in the detailed concept.

Finally, the closely and the loosely coupled approaches are compared in section 5.2.4 in order to advance this discussion. As a result, recommendations are provided that specify in which PDP system environments each approach suits most.

5.2.1 Common concepts of the relevant candidate approaches

Both proposed candidate approaches imply common concepts. These common concepts as well as the approaches are published in (Schanzenberger & Lawrence, 2004, 194-208; extended journal-version in Schanzenberger & Lawrence, 2005, 203-217).

Naming and a brief overview of the candidate approaches

Bauer describes in literature the coupling between a PM system and a WFM system as *closely* if both are incorporated in one system. He identifies a *loosely coupled approach* as two independent systems which communicate with each other (Bauer, 2004, 74-86). This differs from the naming convention which is used in this research project. In the two relevant candidate approaches PDP and PDPM system are always independent systems. The naming is related to their differences in the communication coupling.

The first approach is called *closely coupled*. The closely coupled approach has a bi-directional communication between the PDP and the PDPM system.

The second approach is called *loosely coupled*. This approach deserves this name because the PDP and the PDPM system do not communicate. Instead, the PDPM system queries one-directional the production status in the database of the PDP system.

The common concepts

The common basic concepts are presented in order to simplify the identification of similarities and to increase the comparability of the approaches. The abstract system design concept presented in figure 5.1 has been created as common model. This is an advanced version of the initial model (cp. figure 2.6) provided in section 2.2.4.
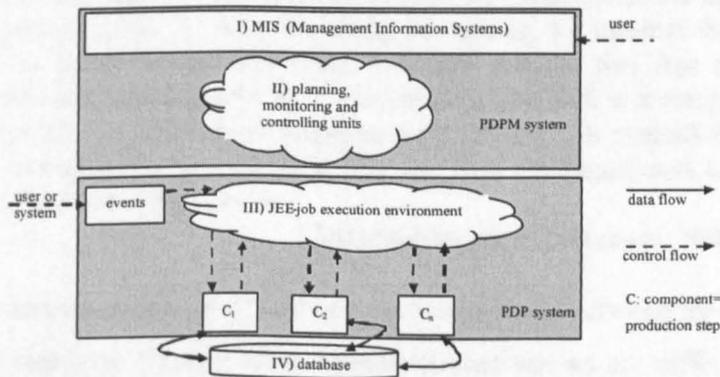
Figure 5.1: Abstract system design concept of PDPM (Schanzenberger& Lawrence, 2005, 210)

The PDPM system: The elements of the PDPM system are a management information system (MIS) (I) for providing production overviews and units for planning, monitoring and controlling PDP (II). Interested users can query these overviews by using the MIS. This MIS provides detailed views on the variable fluctuations and the progress in PDP. Overviews of timing, costs, and resources of PDP and the administration of these features have to be supported. Especially for the timing aspect Gantt and Pert diagrams produced for the needs in PDP are of interest. User interfaces for time planning are necessary to enable the comparison between the planned and the actual production and thus to identify productivity. Comparing the timing of past production periods can help to identify trends and progresses. The MIS has to provide data flow information in form of interrelationships and critical paths to

identify the source data for reports and to overview critical products for the timing. Time management can additionally be strengthened if warnings of current upcoming customer orders are given. Early recognition of prospected delays for customer orders allows to increase the priorities of the implicated jobs in time to speed-up the production process. Moreover, questions of the customer order coverage could be answered by a simulator based on the information of previous production cycles.

Resource management can be enabled in the MIS by showing capacity utilisations, if workers are able to assign their work hours to production jobs. Personnel and production load can then be planned. The MIS can also provide cost management overviews if the production costs are cleverly weighted and correlated to the production jobs. Summarised, all strategic, tactic, and operational management decisions are based on the information provided in the MIS.

The planning, monitoring, and controlling units (II) are essential for planning the timing of production. These units consist of tools for intervening the production progress and for performing the collection of management information. Depending on the layout these tasks are achieved by automation or by user interactions.

The PDP system: A brief overview of the PDP system's features is provided because it is essential to understand the interplay between PDP and PDPM systems. The *job execution environment* (JEE) is an essential component of the PDP system (III). A user or system event transmits the parameters of a data package, which need processing, to the JEE. The JEE identifies the correct production step (C_x), forwards the parameters and starts C_x. Such a production step C_x can raise events with new commands for the JEE to start other jobs (e.g. C_{x+1}). After finishing processing, C_x informs the JEE about success or errors by its exit code. The JEE notices this free server resources and allocates waiting jobs to it. Accordingly, the JEE is a component which enables PDP and which is responsible for a reliable job execution. The database (IV) contains all periodic data (i.e. the data packages) and can be represented by distributed data pools.

(Schanzenberger & Lawrence, 2005, 203-217)

In figure 5.1 arrows which would indicate communication between the PDPM and the PDP system are removed. Exactly these communication arrows are different in both candidate approaches and thus will be presented when discussing them in detail. Other differences are indicated in this figure as clouds, which refer to a deeper discussion of these features in the following sections.

5.2.2 Closely coupled approach

The closely coupled approach is a sophisticated concept for IT-aided PDPM. Its metaphor models are PPS and SFP. The motivating idea is to schedule every single production job to gain a production plan. Thus, a high optimisation degree is achievable if processing as planned is ensured. In this section this approach is described in detail. An abstract system design concept provides overview of the communication coupling between

the PDP system and the PDPM system. Then a detailed system design concept explains the functionalities which are offered by using this approach. Finally, this approach is checked against the identified present problems in PDPM.

The concepts

Planning possibilities: A pre-condition for a high optimisation degree is to plan production jobs and to adhere strictly to this plan. Optimisation can, for example, be supported if less important jobs are scheduled to production uncritical times or if waiting times are reduced. If deviations arise due to changing input data or due to delayed data deliveries, reactively planning is necessary. In these cases the plan has to be rescheduled. Rescheduling might also be necessary if job processing takes longer than expected. To avoid frequent rescheduling, knowledge of the job's duration times, their seasonal behaviour, and waiting times are mandatory.

The 'release-ready' mechanism: To produce strictly as planned means to continuously compare the plan with the current production progress. Thus, the guiding idea is to release jobs when a plan gets active and to inform about job finishing by sending ready-messages.

Using workflow instances: In PDP jobs can often be sequenced and thus bundled to small job chains. Accordingly, workflow definitions can be modelled. Each workflow can be scheduled and instantiated in one piece. Planning can in these cases be simplified, as not every single job needs to be scheduled.

(Schanzenberger & Lawrence, 2004, 194-208)

The high-level system design concept

The high-level system design concept provided in figure 5.1 in section 5.2.1 is extended as the communication arrows between the PDP system and the PDPM system are added in order to explain the concepts of the closely coupled approach. The resulting system design concept for this approach is provided in figure 5.2.
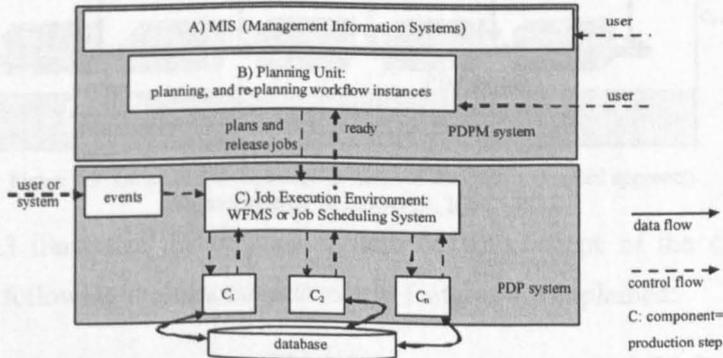
Figure 5.2: Abstract system design concept of the closely coupled PDPM approach
(Schanzenberger & Lawrence, 2005, 210)

In this approach the PDPM system needs to create production plans and to communicate them to the PDP system. When a job is due and free server resources are available, a job-release message has to be sent to the PDP system. Vice versa, if a job (or a

workflow instance) finishes processing, the PDP system sends a job-ready message to the PDPM system. Consequently, the PDPM system is able to prove its plan for correctness and if necessary to initiate re-planning. Due to the complexity problems with planning and re-planning of high job volumes, these tasks might only partially be automated. Users have to manually plan and re-plan production.

The system design concept includes the following building blocks:

A) **MIS:** The MIS is used to inform the management by offering production overviews. It does not differ from the MIS description provided in section 5.2.1 and needs therefore no further explanation.

B) **The planning unit:** This unit supports the users in planning, re-planning and in visualising production plans. Furthermore, background processes are necessary to implement the release-ready mechanism and to transfer active plans to the JEE of the PDP system. Job duration times have to be logged to ensure correct plans.

C) **JEE:** The main task of the JEE is to provide reliable job execution. Moreover, release-messages have to be interpreted for starting jobs and ready-messages have to be sent after job finishing. Plan interpretation informs the JEE about job priorities.

(Schanzenberger & Lawrence, 2005, 203-217)

The detailed system design concept
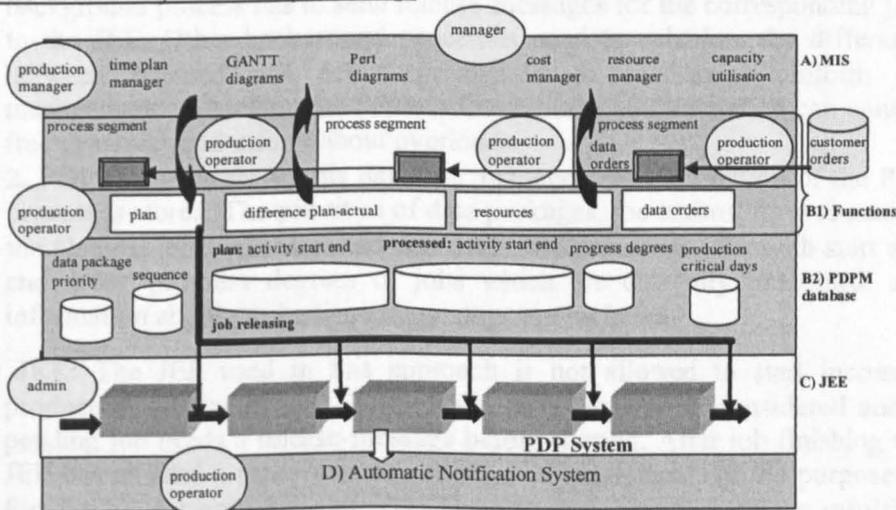
Figure 5.3: Detailed system design concept of the closely coupled approach
(Schanzenberger & Lawrence, 2004, 199)

Figure 5.3 illustrates the detailed system design concept of the closely coupled approach. In the following the functionalities and features are explained:

A) **MIS:** Production manager and higher management use the MIS for decision support in strategic, tactic, and operational questions. Both user groups can be supported with production overviews of different aggregation levels. Expected production overviews are Gantt and Pert diagrams and capacity utilisations. To enable these overviews main modules are introduced. Main modules are a time plan manager, a cost manager, and a resource manager. The time plan manager is a detailed planning possibility as common in SFP.

This tool enables management to correlate workers and servers to production jobs and offers possibilities for re-planning. Accordingly, capacity utilisation can be displayed correctly. This allows the management to plan and to react directly on load and personnel situations. Additionally, for the purpose of selecting and storing information the MIS uses the PDPM database.

B) 1. Functions: Data orders are derived from customer orders. Each data order has a specific deadline and is backwards propagated to inform the process segments ahead. Data orders are translated into each process segment's specific product keys to meet the changing product identifiers. From these data orders production jobs are created in advance. These jobs are sequenced where possible and sorted into a production plan by using JS algorithms. The duration times of these jobs are estimated by using corresponding jobs from former production periods and adding the measured waiting times. Results of these calculations are the specific deadlines for the data orders.

The plans can be influenced by using the time plan manager in the MIS. Active plans have to be send to the JEE as well. Production operators of the process segments can thus be informed about data orders, their deadlines, and pending jobs. A background process for data order administration creates the jobs, plans, and calculates the data order deadlines. Background processes also have to be implemented to establish the release-ready mechanism. If a plan gets active and free resources are available, the background process has to send release-messages for the corresponding jobs to the JEE. Other background processes need to calculate the difference between planned and actual production to accordingly inform the management. A background process for resource administration can control free resources and inform about overloads.

2. PDPM database: In this database, management information of the PDP process is stored. The priorities of data packages, the control flow sequence, the planned jobs with start and end dates, the processed jobs with start and end dates, progress degrees of jobs which are currently processed, and information about production critical days are included.

C) JEE: The JEE used in this approach is not allowed to start incoming production jobs as queued. The active plans have to be considered and a pending job needs a release-message before starting. After job finishing the JEE has to send a ready-message to the PDPM system. For the purpose of forwarding not only the exit code but also the identifiers of the resulting data packages from a finished production step to its successors, usually each of the production steps need to be extended.

In this case, the JEE can be a WFMS or an advanced JS system, which is able to work with job chains. Each of these system types is able to meet these conditions. This might be advantageous because commercial WFM or JS systems support correct scheduling, reliable job execution, and error handling. However, neither WFMS nor JS systems are able to use their particular efficiencies as their tasks are reduced to simple job execution mechanisms. This is due to the close coupling between PDP system and PDPM system.

D) Automatic notification system: If production steps end with errors a message is sent to the 'automatic notification system'. Triggered by this

message, this system informs production operators accordingly. Thus, errors, warnings and also other events can easily be forwarded. If the event descriptions are attached to e-mails a world-wide notification is possible in a distributed PDP process. This sub-system contributes to proactive error handling and consequently for production optimisation.

(Schanzenberger & Lawrence, 2005, 203-217)

Evaluation of this approach

Advantages and disadvantages of the closely coupled approach are discussed in the following regarding the identified present problems in PDPM (see section 4.4):

1. Evaluation regarding the problems arising due to coping with PDP specifics

- The changing product identifiers are addressed; as data orders are translated into each process segment's specific product keys. However, this translation and the assignment of data orders to specific jobs is not easy. Former production periods are used for this identification. The risk is that this former production periods have been differently processed due to a high number of deviations in the former or in the planned period. Accordingly, the correctness of the estimations in case of job plans and data order due dates depends on the number of deviations.

- Key performance indicators can be derived from the job log.

- As each single job can be tracked, the PDPM system can provide very detailed production overviews on the job layer.

- As data package identifiers need to be forwarded to production step's successors, these legacy applications (i.e. production steps) usually have to be enabled to do so by changing their program code.

- In addition to producing the periodic data, in this approach different message types are used to enable PDPM. Data orders are forwarded to the process segments. Release-messages are sent from the PDPM system to the PDP system. Ready-messages are sent from the PDP system back to the PDPM system. All these messages need to be calculated, created, and administrated. This results in a high additional communication effort. Prior to the implementation of this approach it is equally necessary to prove whether the PDP system and the environment of the PDPM system is satisfyingly scaled for the extensive communications. Due to the close communication coupling between the PDP system to its PDPM system there is additionally the risk to slow-down production itself.

2. Evaluation regarding the difficult observation of the data flow

- The dependencies between production jobs are stored in the production plans. As

these jobs and the data packages are correlated, the data flow can be queried. Aggregations and separations are not a problem as predecessor and successor relationships are stored between the corresponding jobs.

- Job logs can be used to query the past, current and planned data flow.

3. Evaluation regarding planning problems

- The problematic handling of both deviation types remains in this case often a manual task due to the limits of automated planning. The availability of sufficient manpower is an argument when discussing this approach.

- To some degree manual re-planning in case of deviations during run-time is necessary and complicates the time management of PDP. Accordingly, one factor that decides over success by using this approach is the average number of deviations. The lower this number the more likely is the success.

- The appeal of this approach is that the achievable optimisation degree can be very high. This depends on the effort planners spend for planning. Waiting times can effectively be reduced. If the plan is assumed to be created under strict optimisation rules as in this approach, working as planned is effective.

- Differences between actual production and planned production can be measured because plans are available. Without plans, productivity can just be calculated when comparing past production periods.

- Detailed planning as proposed in this approach enables accurate balancing of resource loads.

4. Evaluation regarding ignoring the repetitive character in PDP

- Duration time of jobs is logged and is used as pre-setting in the next production periods. Appropriately, the repetition is considered. This includes that seasonal fluctuations in duration times need to be recognized and handled correctly.

5. Evaluation regarding the difficulties with this distributed environments

- The organisation of all PDPM features is centralised. The MIS can be implemented as web-pages to ensure world-wide access. Functions, PDPM-database, and the automatic notification system are placed on the central location. From this centralized point data orders are distributed, and messages (e.g. release, ready or notifications) are sent and received. Message queues can be used to communicate asynchronously. Computational power can thus be centralized for the complex planning algorithms. The distributed PDP system is sufficiently controlled.

5.2.3 Loosely coupled approach

The loosely coupled approach is of interest for PDPM because both systems, PDP and PDPM, work almost independent from each other (i.e. PDP and PDPM do not interact). Instead of communication between the both systems, PDPM requires only querying status information in the database of the PDP. Its metaphor model is PM. In this case PM has been advanced to work with the repetitive character of PDP. The basic concepts of milestones have been extended to provide PDP schedules. Milestones are cleverly assigned to product identifiers in order to enable data flow tracking. Accordingly, PDP is never delayed due to coupling to other systems, and production overviews as common in PM are achievable. In this section the loosely coupled approach is described in detail. An abstract system design concept is provided to visualize the coupling type of the communication. Then, its detailed system design concept is used to discuss the functionalities of this approach. Finally, this approach is evaluated by using the identified present problems in PDPM.
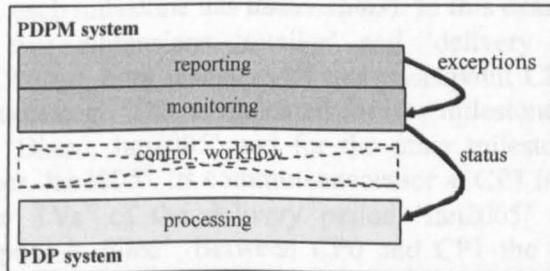
The concepts

Figure 5.4: Checking the production status in the loosely coupled system design concept

Status checking instead of WFM: The guiding idea of this approach is to frequently monitor the processing status by querying production (see figure 5.4). The status monitored is not the result of each production job, so there is no need for a workflow layer. In fact, the state of an object is checked against a pre-defined set of production states. Only exceptional production behaviour and its status is reported to PDP managers. Production plans are therefore not necessary in this approach.

Content-aware milestones: The consequence of discarding job plans is that the basic concepts of milestones become attractive. They are popular and well established elements of PM. Traditional milestones have a due date and are activities without duration times. Respectively, they are suitable for scheduling only the most interesting transactions in this case. Milestones which are useful in PDPM have to be enriched with product identifiers (i.e. data package assignments) and progress degrees (e.g.. processing at a specific production step is completed to X%). These *content-aware milestones* are thus able to deliver status information about PDP. Data content is accordingly related to production status and timing. Current production situations ('what' is produced now, and 'how' is the progress), can be easily controlled.

To bundle milestones after specified process sections, **checkpoints** are introduced. They represent the different points of interest in the production process and are templates for the content-aware milestones. Milestones are therefore only allowed on these checkpoints. A pre-condition is, all production data must pass these checkpoints. The checkpoints as well as the milestones have predecessor-successor relationships. They form a directed acyclic graph and can easily be mapped and stored in databases.
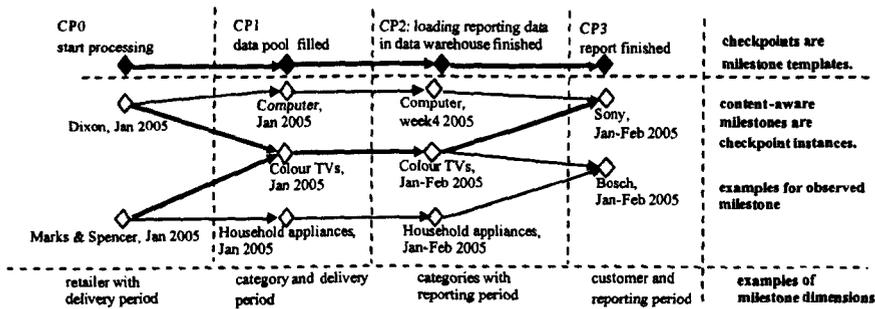
Figure 5.5: Simplified example of content-aware milestones in market research
(Schanzenberger & Lawrence, 2004, 203)

Data flow tracking: As milestones are content-aware they can be used excellently for data flow tracking. The production overview gained is demonstrated in the following example from the market research area. In figure 5.5 there are four checkpoints (CP0-CP3). At each checkpoint milestones are instantiated. The product identifiers of data packages are assigned to milestones (i.e. each milestone has *dimensions*). In this example a milestone at CP0 has the two dimensions 'retailer' and 'delivery period'. The two milestones at CP0 are both instances of this checkpoint CP0 which indicates the 'start of processing'. This is indicated for one milestone in the case of the data packages 'Dixon, Jan2005' and for the other milestone in the case of 'Marks&Spencer, Jan2005'. Its common successor at CP1 is a milestone of the category 'Color TVs' of the delivery period 'Jan2005' and indicates if a specific 'data pool is filled'. Between CP0 and CP1 the product identifiers change therefore from 'retailer' to 'category' (i.e. a change of dimensions between CP0 and CP1). If it were now assumed that the category *'Color TVs''* must be reported bimonthly, the reporting period, a dimension of CP2, would then be *'Jan-Feb2005'*. One of its successors in CP3 indicates that the end product 'statistical report over Color TVs' would be delivered after extrapolation to a customer (e.g. *'Sony'*) based on the reporting period *'Jan-Feb2005'*. Since all milestones have due dates, production operators can be informed about content and delays in their PDP.

Showing production progress: Each milestone has a completion degree. This completion degree is not related to the finishing of the end-reports. In this case it is related to the milestones completion itself. A milestone is said to be completed to 100% if the assigned data package has passed this milestone. This is simple to measure and the current production status can easily be identified.

Look-ahead: There is a need not only to track the current production, but also to inform production operators about the production in the near future. Accordingly, milestones have to be created in advance with a short look-ahead. They can be created in advance if planned dates of arriving data packages are gathered. The times between adjacent milestones in past periods can be used to calculate the timing of the whole milestone chain in advance. The milestone

history is thus the base for estimating the milestones of future production periods themselves, their due dates and their relationships.

Planning possibilities: The idea for automating the planning is, to introduce '*due date rules*' for milestones. Each rule can have the milestone dimensions to specify specific data and a rule template. A rule template is for example 'x.th working day of the next month'. Thus, an example for a rule is '5.th working day of the next month, for all milestones with monthly delivery periods'. Such a rule can also include the time span between two checkpoints (e.g. milestones of CP_{x+1} can apply to the rule 'CP_x plus 2 hours'). The specific due dates of milestones can therefore be automatically calculated, if the rules are once implemented.

(Schanzenberger & Lawrence, 2004, 194-208)

The high-level system design concept
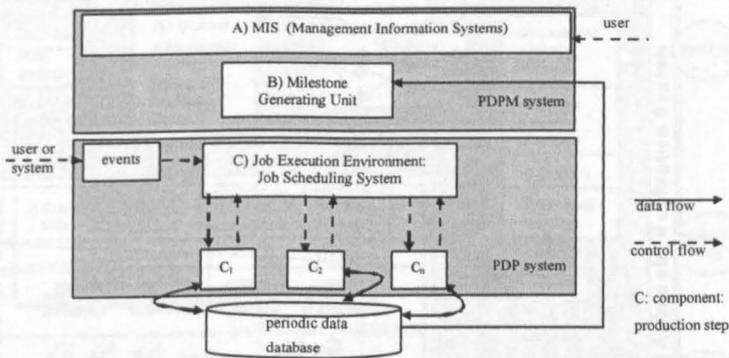
Figure 5.6: Abstract system design concept of the loosely coupled PDPM approach
(Schanzenberger& Lawrence,2005,212)

The high-level system design concept provided in figure 5.1 in section 5.2.1 is complemented here as the communication between the PDP system and the PDPM system is added to explain the concepts of the loosely coupled approach.

Figure 5.6 demonstrates that the PDP system does not need to communicate with its PDPM system. Thus, both systems are almost independent and have no interrelationships. The advantage is, there is no risk to slow-down PDP due to the communication with other systems. Instead, the PDPM system only queries the production progress in the PDP's database. This is necessary in regular intervals to keep the PDPM system up-to-date. The interpretation of this system design concept's building blocks is the following:

A) **MIS:** Production overviews are presented to the management. The description of this MIS is analogue to its description in section 5.2.1 and is therefore not extended.

B) **The milestone generating unit:** The creation of milestones can be automated as the complete volume of PDP has to be represented. Consequently, background processes are required for generating the milestone chains and querying the production progress. In the milestone history the times are logged where milestones change to the status 'completed'. Additionally, a user interface for creating the rules of due dates is necessary for automating the planning.

C) JEE: The main task of the JEE is to provide reliable job execution. The JEE can concentrate on this task and does not need to be extended for offering any additional features.

(Schanzenberger & Lawrence, 2005, 203-217)

The detailed system design concept

In figure 5.7 the detailed system design concept of the loosely coupled approach can be seen. The proposed functionalities and features are outlined in the following:
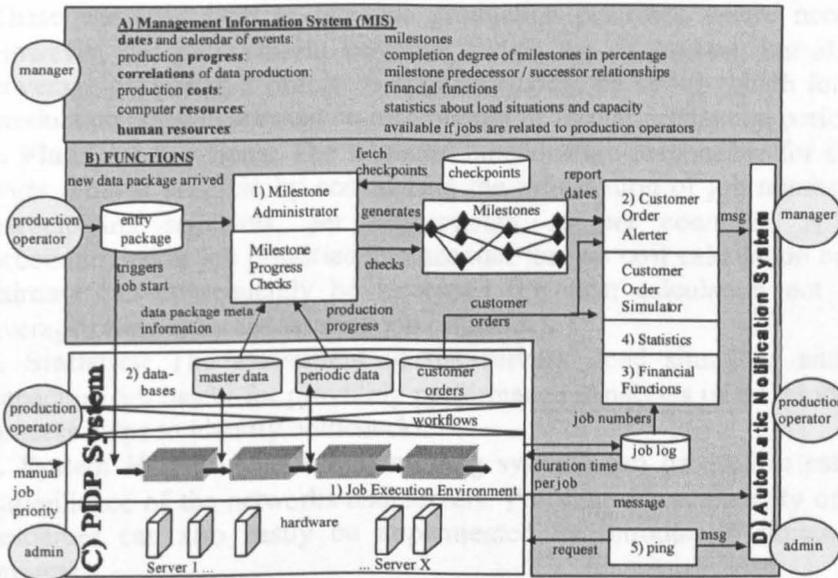
Figure 5.7: Detailed system design concept of the loosely coupled approach (Schanzenberger & Lawrence, 2004, 201)

A) MIS: Specified strategic, tactic and operational management questions can be answered with the MIS. Decision support for production manager and higher management can be supported with different production overviews by using different aggregation levels. For a calendar of events the milestones can be used. The progress in production is represented by the completion degrees of milestones. The data flow can be tracked by using the milestones predecessor and successor relationships. In PM the Gantt and Pert diagrams can be based on milestones. Thus, both diagrams can excellently be derived in this approach. All these production overviews can consequently be queried in the milestone database table and its history. In contrast, production costs and resource management is based in this approach on the job log. The share of costs can be distributed on job volumes. Statistics of server resources can be used to control load situations and capacity. If clever logon-mechanisms are provided (e.g. identification of production operators and their assignment to production jobs) human resource capacities can be estimated.

B) Functions: 1. Milestone administration: The generation of milestones can be fully automated. Background processes are necessary for this automation (cp. section 6.3.5). If a production operator enters a new data package at the data entrance, this event is sent to the centralised PDPM system in form of 'entry package messages'. This message is recognised by the *'Milestone Administrator'* process. This process creates all necessary milestones at each checkpoint and all the predecessor/successor relationships between

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them. This is done by querying production and the milestone history. Production can also be planned in advance. The look-ahead in production is estimated by interpreting the rules of the due dates, as also entry packages can be planned by using such rules. The *'Milestone Progress Checks'* process proves in regular intervals the status and progress of milestones. This is to identify the difference between planned and actual production to inform management accordingly.

2. Customer order tools: For the identification of critical data in production, an alerter is suggested to warn when customer orders are due. These warnings help to increase production priorities where necessary. However, not only current customer orders are of interest, but also the coverage of customer orders. A simulator could be set up which forecasts production behaviour based on information of former production periods.

3. Financial functions: The financial functions are responsible for sharing costs. This is possible by considering the information of job numbers per participating segments, per departments, or per countries. A smart accounting takes job priorities into account for this cost calculation because fairness can consequently be increased (i.e. cost calculation not on an average base but by considering job priorities).

4. Statistics: The assessment of the servers' load situations and their capacities are useful for providing performance. Analyses of the production process helps to identify bottlenecks.

5. System Health: Network monitoring systems can be used to establish surveillance of the networks and servers. Proofing the availability of these resources can also easily be implemented by introducing simple ping-programs.

C) JEE: As already explained in this section, there is no need for a workflow level in this approach. The only responsibility the JEE has, is reliable job execution. The scheduling of jobs is not obstructed as this system can run independently. The PDP and the PDPM systems have no direct connections. Consequently, the JEE can clearly be a JS system or any commercial representative in this case. These systems are able to control system health and contribute thus to performance. Job logs are usually guaranteed. An advantage is, all legacy applications, as for example production steps, can be used without any changes. The reason is, exit codes from this applications are sufficient to inform the JS system about success. However, without any corrective actions, jobs would be processed after the FIFO principle (First-In-First-Out). This situation can be improved by introducing priorities to data packages. Once this priorities are assigned, the JS system can be enabled to run the corresponding jobs accordingly. The processing of important end-reports can thus be speeded-up. In contrast, waiting times due to processing bottlenecks cannot be avoided sufficiently. The result is optimisation can only be achieved to a certain extent. However, as long as enough system resources are available this fact is not crucial important.

D) Automatic notification system: This system is notified if production steps result with errors. Such errors, warnings or other possible events trigger this system to send e-mails to registered users. Production operators can then be actively and immediately informed about important events and waiting times of production operators can be optimised.

(Schanzenberger & Lawrence, 2005, 203-217)

Evaluation of this approach

The identified present problems in PDPM (see section 4.4) are discussed in relation to the advantages and disadvantages of the loosely coupled approach:

1. *Evaluation regarding the problems arising due to coping with PDP specifics*

    -   Content-aware milestones address the changing product identifiers as each milestone has dimensions which relate to these keys.

    -   Key performance indicators can be derived from milestone states (e.g. the number of delays can be used to measure productivity).

    -   Production overviews on the milestone level are achievable. Representatives of Gantt and Pert diagrams can be used because milestones do cover these chart types.

    -   Production overviews on the job level are not possible in such a PDPM system because dependencies between jobs are not available. In this case, jobs can only be queried in the job log provided by the JEE. In contrast, introducing new production steps in PDP is not a problem for the PDPM system, as milestones are on a higher level.

    -   This approach requires that milestones are frequently checked for correctness. Milestones have to be deleted, others have to be created and relationships between milestones change from time to time. The risk is, that the timeliness of the production overviews suffers due to these checks.

    -   The more frequently the PDP database is polled, the more accurate the production overviews in PDPM can be in real-time. However, the risk is a decrease in database performance can be the consequence due to frequently polling the PDP database. Last but not least, this can lead to a decrease in PDP performance. Optimising the queries is the key to prevent this performance loss.

2. *Evaluation regarding the difficult observation of the data flow*

    -   Data flow tracking is excellently possible with content-aware milestones. This approach is beyond the scope of life-cycle management and offers possibilities to track past and future production periods.

    -   The past periods can be tracked via the milestone history, the current production periods via the current milestones, and the future production periods are predicted via the milestones which are prospected as look-ahead.

    -   The predecessor and successor relationships address the problems with aggregations and separations as demonstrated in the example depicted in figure 5.5.

3. Evaluation regarding planning problems

- Both deviation types, which arise during run-time, are manageable. Delayed data packages can be prioritised and accordingly faster production is possible in these cases. Changing input data is treated in the same way as normal production. Those data packages are entered and processed as usual.

- No manpower-consuming re-planning is necessary. Scheduling algorithms are not required in the PDPM system. It is sufficient to interpret rules for the identification of due dates. Manual effort is to introduce the rules only once. The deviations which arise during run-time are processed as they come in according to their priorities.

- However, the maximum of optimisation is not achievable by using this FIFO (First-In-First-Out) production. Bottlenecks in production cannot always be prevented. Waiting times during processing can occur.

- Tracking the changing product identifiers is possible because of the predecessor and successor relationships between the milestones. Thus, the data sources of the end-reports can easily be identified by analysing the relationships.

- As there exists no detailed plan the current production cannot be validated against its plan. Only former production periods can be compared after production is finished. Current delays in production can only be treated by changing the priorities of jobs, as it is not possible to forecast delays.

4. Evaluation regarding ignoring the repetitive character in PDP

- The repetition in PDP is used in this approach to fully automate the milestone generation. The due date rules can be easily optimised from production operators. Thus, waiting time reduction is possible. Moreover, human resources are the most expensive factors in PDP. In this approach they are only applied to production relevant tasks as they do not need to create milestones. Production operators can query the milestone schedules without additional effort. This is very useful as production costs should not be increased by introducing PDPM.

- An advantage of this approach is that the PDP system runs almost independent and delays in production will never be caused by the PDPM system. To be independent means that the PDP system and PDPM system do not interact with each other, but PDPM only queries the production status from PDP by using, for example, the information which is available in the production log. Thus, large data volumes and performance problems are rather a problem of the JEE than issues in PDPM.

However, milestones need to be created for the whole PDP. Thus, a high number of milestones is expected. The automation of the milestone generation is therefore an additional load and a risk for performance problems of the PDPM system. Furthermore, entry package messages create additional communicational effort. The high level of milestones (compared to the detailed job level) helps to reduce this additional load as far as less milestones than jobs are generated.

5. *Evaluation regarding the difficulties with this distributed environments*

- The distributed PDP can be tracked as follows. The milestone generation is centralised to ensure scalability and load balancing.

- The MIS is a web-tool where world-wide access is provided.

- Entry package messages and event notifications are sent to this centralised PDPM system. Asynchronous message queues are useful in this case.

- Instance handling of production steps is not a problem as the job level is not considered in this PDPM approach.

5.2.4 Comparison of the closely and loosely coupled system design concepts

Main goals of this research project are to provide knowledge to the research community and decision support for system designers. To facilitate this it is useful to compare both relevant candidate approaches for PDPM (see section 5.2.2; section 5.2.3) and to identify the PDP environments in which they are applicable. The main finding is, both are useful but in different cases. Recommendations of useful implementation areas for both approaches are finally presented. This comparison is published in (Schanzenberger & Lawrence, 2004, 194-208) and as an extended journal-version in (Schanzenberger & Lawrence, 2005, 203-217).

Criteria for this comparison

Concrete criteria are useful when comparing potential system design concepts. They improve the quality of a comparison, as the same issues are discussed for all candidate approaches and this discussion follows a given order. The criteria listed in table 5.2 are used in this research project to compare the both candidate approaches.

Questions	No.	criteria for a comparison of the proposed approaches
WHAT kind of new and automated PDPM is proposed?	A	Which metaphor model from literature is used? It is usually recommended to use proven and established metaphors when searching for a system design concept.
	B	What type of IT-aided management is used? Is planning, controlling, and monitoring supported in full? Has the approach strengths or weaknesses regarding planning, controlling, or monitoring functionalities?
	C	What types of control are used in an approach? What kind of control needs to be conducted manually and what can be automated? For example, can each activity have a default priority or is manual activity re-planning the strategy?
HOW is the automated PDPM conducted?	D	Which level of supervision is best? For example, appropriate supervision might consider each activity in the PDP system or might only deliver aggregated overviews.
	E	How and to which degree is optimisation achieved? Is it achieved manually by staff members or through automation?
	F	How responsive are the different approaches in relation to production and to supervision? For example, is it possible that PDP is delayed through re-planning methods or is it the other way around? Is supervision done quickly or delayed by many manual tasks?
	G	How large is the effort and expenditure to conduct supervision, to implement it and to develop the needed user interfaces?
	H	What kind of support is given for organisational levels (e.g. statistics for management, production overview for operators, etc.)?
	I	Does the approach work with legacy applications?
WHEN is which approach recommended?	J	For what type of periodic data production system is a particular design concept recommended?

Table 5.2: Criteria for comparing relevant candidate approaches (Schanzenberger & Lawrence, 2005, 214)

Comparative analysis

PDP systems include a high complexity. Thus, various different PDP systems are possible. The consequence is that there will never be only one single correct solution for PDPM. This insight is a result of observing PDP in industry and the discussion of approaches identified for PDPM so far. The discussion also shows that theoretical research towards informative categorisation of high-quality approaches is very useful and an urgent need prior to implementing a PDPM system. The advantages and disadvantages of the both candidates are investigated in the following by using the criteria introduced in table 5.2:

A) The used metaphor models: The closely coupled approach is based on the metaphors PPS and SFP. Both are established approaches for the computerized supervision of goods production. Their design concepts demonstrate how goods production can be optimised by producing strictly as planned. They are attractive as a high optimisation degree is possible by using them. For this reason the management system is closely coupled to the production system. The proposed closely coupled approach engages these proven features of the metaphors and adjusts them for PDPM. This is because PPS and SFP systems themselves are not applicable in PDPM due to the differences between goods production and PDP. However, especially the SFP mechanisms (i.e. detailed planning) can be transformed for PDPM. These mechanisms are used in the closely coupled approach for its planning unit. This planning unit communicates with the JEE of the PDP system. Unfortunately, the focus in this approach lies on the control flow management of jobs rather than on data flow management. Nevertheless, as jobs are always related to data packages, the data dependencies can be queried by using the job dependencies. Another

disadvantage is, a high communication effort is expected for tens of thousands jobs a day due to the used release-ready mechanism.

The metaphor model used for the loosely coupled approach is PM. Projects in PM are usually not repeated. Thus, representatives of PM systems are not applicable in PDPM. However, the proposed loosely coupled approach uses the concepts of milestones and adjusts PM for the computerized supervision of repetitive PDP environments. Milestones are enriched with product identifiers and production progress degrees. Predecessor and successor relationships between milestones enable thus data flow management. Appealing is, that the milestone generation can be fully automated by taking advantage of the repetitive character of PDP. This automation can be achieved by using only a loose coupling between the proposed PDPM system and the PDP system. A loose coupling is sufficient to simply query the progress of production in the PDP's database. On the one side no communication between PDPM system and PDP system is necessary. On the other side, the optimisation potential of this approach is lower than the one in the closely coupled approach.

B) Type of management functionalities:
B.1) Degree and type of planning: A disadvantage of the closely coupled approach is that the manual planning effort is expected to be high. New planning and reactively planning during run-time can to a certain degree not be automated, today. The calculation complexity limits planning automation when processing high job amounts. However, the availability of plans as usual in this approach allows for comparing the previous and current production to these plans. Correspondingly, production overviews of delayed jobs can be provided and key performance indicators (e.g. productivity) can be derived.

Milestone generation can be automated when using the loosely coupled approach. The advantage is, the manual planning effort is reduced to a minimum. As PDP is repetitive, planning the milestones' due dates is a one-time job. Once due date rules are introduced, the planning for future periods is then automated. In this approach the milestone chains are created in advance. However, there is no detailed production plan. The consequence is, the current production cannot be validated against such a plan. Accordingly, a disadvantage of this approach is, only former production periods can be compared.

B.2) Degree and type of monitoring: Planned and current activities are monitored in detail in the closely coupled approach. This means, each production job is monitored. Accordingly, a job history is available. Job chains, coherences between jobs, and load situations can be overviewed.

The aggregation level of the milestones used in the loosely coupled approach is higher than the job level. Not each job is monitored, but the completion of milestones is the focus. Therefore, more than one job can be necessary to complete a milestone. For this reason, the status of the milestone is queried in the production database. The last incomplete milestone in a chain informs how far production has progressed. Thus, a milestone history is available. Milestone chains and coherences between milestones can be overviewed. In contrast, load situations have to be analysed by using the job log of the JEE.

B.3) Degree and type of controlling: The planning unit offers the control possibilities for PDP in the closely coupled approach. For this purpose this tool has to enable new plan creation and reactive planning. Manual as well as automated planning functionalities have to be included. The assumption is, that the resulting production plans are optimal as they have been manually proven. Resultantly, no bottlenecks in production are expected.

In the loosely coupled approach the control possibilities of PDP are focused on adjusting the milestones' due date rules. All jobs which are related to these milestones run after the FIFO principle and are given job priorities. Out of this, bottlenecks in production can sometimes occur.

C) Contingent and type of control: The closely coupled approach offers support for manual control by enabling reactively planning, by providing e-mail notifications in case of production errors, and by using the possibility to set breakpoints during production if supported by the WFM (or the JS) system. Automation can only sometimes be provided in the case of plan creation, as planning algorithms have limits in relation to high job volumes. However, the creation process of the production overviews where plans are compared to past and current production, can be automated.

The loosely coupled approach offers support for manual control by enabling the changes in job priorities, by providing e-mail notifications in case of production errors, and by using the possibility to set breakpoints during production if supported by the JS system. In contrast, milestone generation is fully automated. Additionally, the creation process of the production overviews where milestones of former production periods are compared is automated.

D) Level of computerized supervision: Management overviews in the closely coupled approach can be provided on the very detailed job level because the jobs are planned and monitored. The advantage is, very precise data can be shown in the production overviews. The disadvantage is, the PDPM system has to cope with high job quantities.

The level for the computerized supervision in the loosely coupled approach is not as much detailed as in the closely coupled approach. Milestone dimensions are usually aggregated job dimensions. However, the advantage is that the amount of PDPM data can be reduced. The disadvantage is, production overviews are not provided on the detailed job level.

E) Optimisation degree: Appealing in the case of the closely coupled approach is the high optimisation degree which is achievable. Every single job can be optimally planned. This prevents bottlenecks in production. Good throughput times for jobs are achievable. However, the disadvantages are work time for reactive planning has to be invested and the automation of the planning activities is limited. Moreover, the risk is to decrease the throughput for production in total, due to the need for slot reservation and re-planning.

The disadvantage of the loosely coupled approach is, that the optimisation degree is not ideal because jobs can only be speeded-up by changing their job priorities. Therefore, bottlenecks can sometimes occur. The throughput times of jobs might not be optimal due to using the FIFO principle. However, the advantage is, a high automation degree is achievable. Milestone generation is automated. As this approach supports the elimination of waiting times, the throughput of production in total can be increased.

F) Responsiveness:

F.1) Responsiveness of the PDP system: Resource conflicts are usual when using the closely coupled approach. This close coupling can be the reason for production delays. In this approach jobs are not immediately executed when they come in, due to the release-ready mechanism. Start times of jobs are fixed. Re-planning of jobs is thus an urgent pre-condition. The consequence is, the responsiveness of the PDP system might be reduced as some time slots might not be used optimally.

There does not exist a connection between the PDP system and its PDPM system in the loosely coupled approach. As a result, no resource conflicts and no delays can occur due to the use of computerised supervision. The PDP system has an excellent responsiveness.

F.2) Responsiveness of the PDPM system: In the closely coupled approach ready-messages are sent asynchronously from the PDP system to the PDPM system. Correct reactions in the PDPM system can therefore be delayed if the PDP system is not able to inform the PDPM system in time. The responsiveness of the PDPM system can for this reason sometimes be reduced.

As the PDP system and its PDPM system do not communicate with each other, the responsiveness of the PDPM system is not interrupted due to any couplings.

G) Effort and expenditure:

G.1) Effort to conduct PDP supervision: Human planners are necessary in the case of the closely coupled approach. They are responsible for creating optimal production plans. Previous, current and future resource bottlenecks can be easily identified by comparing the plan with the actual production. Re-planning is only necessary in the case of deviations or production problems. Therefore, manual effort for PDP supervision might be high.

When using the loosely coupled approach, production operators only change occasionally job priorities or due date rules. In this respect, the manual effort for PDP supervision has not been evaluated as high. However, only past resource bottlenecks are identifiable, as there are no production plans.

G.2) Effort of concept implementation: The closely coupled approach uses a planning unit and a WFM (or an advanced JS) system. The effort to implement this concept for large job quantities is high. One reason is, the communication mechanism between the PDP and PDPM systems need to be developed. Another reason is, the scalability of the PDPM system has to be thoroughly chosen to guarantee an uninterrupted interplay between the PDP and the PDPM system. There might be an additional effort for production operators to create workflow definitions during design time. Manpower necessary for the re-planning during run-time needs to be provided with respect to the expected job quantities.

The loosely coupled approach can use a JS system representative. Since there does not exist a commercial representative for the milestone generating unit today, this needs to be developed. However, only few checkpoints have to be developed because of the aggregated production overview (cp. example presented in section 6.3.2). Once established, the maintenance effort and the effort to intervene in production during run-time is low. Another advantage is, the user interfaces (e.g. production overviews) can be fast and effective as no drill-down to the detailed job level is necessary.

H) Support for the organisational levels
H.1) Management: In both approaches Gantt and Pert diagrams are suitable production overviews. Alerter for pending customer orders and simulators for future work load estimations are useful enhancements in both approaches.

In the closely coupled approach job plans are available. Resource capacity management and cost management can be related to the production jobs.

Gantt and Pert diagrams have to be adjusted when using the loosely coupled approach (see section 7.5.4.2; appendix E.1.1). Both diagram types have to be related to the data flow rather than to the activities (i.e. jobs). Time plans can be provided as milestone overviews. Predecessors and successors show the relationships of the data flow. Resource and cost management have to be related to the production jobs.

H.2) Production operators: In the closely coupled approach planners are a need. In contrast, the loosely coupled approach does not need planners. Production operators can overview the milestones if required. Both approaches notify production operators via e-mail in case of errors or problems.

H.3) Administrators: Both approaches need system administrators to keep the systems alive and to maintain the production resources.

I) Support for legacy applications: In PDP the legacy applications are the production step programs. In the case of the closely coupled approach, their code needs to be changed, because the WFM system needs to get information about the job's duration times, exit codes, and the product identifiers of the processed data packages. This is necessary to notify the PDPM system accordingly.

Legacy applications do not need code changes in the loosely coupled case, as the PDPM is not related to the job level. Informing the JEE about successful job execution by returning exit codes is sufficient in this regard.

J) Decision support for choosing a system design concept for PDPM: The main advantage by using the closely coupled approach is the high optimisation degree which is achievable. A measuring of the differences between plans and current or past production is possible. Resource problems are predictable. However, one of the main disadvantages in the case of PDPM is the strong similarity to the workflow techniques. This is, jobs have to be planned. Thus, an enormous manual planning effort is expected. Efficient planning algorithms are still an open research area (Brucker, 2001, 1-10). In addition, the release-ready mechanism must be implemented to enable communication between the PDP and the PDPM system. Accordingly, the implementation effort is expected to be high.

Using this approach can consequently be recommended for PDP systems with strongly restricted resources, because planning then makes sense. The majority of jobs have relatively long and/or predictable duration times, as this facilitates planning. More likely are small to medium sized PDP systems where only a small number of data packages are expected. The work hours of the planners should be estimated in relation to the number of expected jobs and their deviations. Only few deviations should arise during production. Enough time should be allowed for re-planning these unforeseen events. Summarised, this approach is useful, if only few deviations arise and (re-) planning can be reduced to a minimum.

The main advantage of the loosely coupled approach is the independence of the PDP system. The PDP cannot be delayed as result of messages communicated between the PDP system and its PDPM system and thus PDPM is independent from the job layer. Planners are not required and milestone generation can be fully automated. This approach has to be developed by programming, but it is easy to implement, as there are almost no dependencies to other systems. Disadvantageous is, that the ideal optimisation degree in production is not achievable because production is only optimised by assigning job priorities. Resource problems are not predictable due to the lack of production plans.

The loosely coupled approach can be recommended if large quantities of deviations are expected during run-time and if resources are not strongly restricted. This is because deviations are automatically identified and corrected, and if the resources are not strongly restricted, there is no need to take the effort for detailed planning. Allowed are jobs with high fluctuations in their duration times or jobs with diminutive durations. In addition, this approach can be sufficiently scaled for coping with high numbers of data packages due to its independency. Accordingly, even large-sized PDP systems are suitable for this approach. The milestone concept used does not track every single job and provides production overviews on an aggregated level. This reduces load and helps operators to focus on the major point of interests. Between checkpoints it does not matter how many production steps are used or if new production steps are introduced. Summarised, this approach is very flexible as milestones are automatically generated, legacy applications need not to be changed, and comprehensive production overviews can be offered.

(Schanzenberger & Lawrence, 2005, 203-217)

5.3   The generic problems solved with the proposed concepts

A generic problem in IS practice is how to put a management system on top of an unchangeable production system. Both system design concepts presented in this thesis demonstrate that this is possible. The experience with these concepts shows that mainly two key issues need to be addressed in order to achieve a federation between a management system and its production system without the need to integrate both systems. This is first of all a suitable communication coupling and the second is to implement robust interfaces between both systems. The coupling of the communication can range from a full message transfer in both directions up to minimal state querying in production logs. The preferred solution depends on the possibilities of the production system to send, receive and queue messages, to be interrupted or delayed during heavy message loads, and to wait for commands from the overlying management system. In addition, the interfaces of both participating systems should be robust in order to be consistent against program revisions. For example, interfaces which are available for exchanging messages could use proven standards such as XML.

Furthermore, it can be advantageous to centralise the management system in case if the production system is distributed. This offers all participants a common basis. Accordingly, management information is standardised for all participants. Access to the centralised system can, for example, be assured by using web technology. A message exchange between decentralised parts of the management system is then not necessary.

5.4 Chapter summary

The aim in this chapter is to discuss relevant system design concepts for PDPM (see section 5.2). Each of these approaches is evaluated by comparing the problems which have been identified for PDPM (see section 4.4). First, the *closely-coupled approach* is introduced which is based on the metaphor models PPS and SFP. Secondly, the *loosely-coupled approach* is described. The metaphor model used in this approach is PM. In either approach, dates, costs, resources, and system health information is made available to management, production operators and administrators to support transparency in PDP. Both approaches are useful, but in different cases. The main advantages of the closely-coupled approach for PDPM are that a large optimisation degree is achievable and that job plans are provided for a detailed production overview. It is useful for computerized supervision of small- to medium-sized PDP systems in cases where only few deviations are expected during run-time, as planners are required for manual (re-) planning.

The main advantages of the loosely-coupled approach for PDPM are, that job execution is independent and unhindered from PDPM and that legacy applications can be used without adapting their code. A sophisticated time management is provided by milestone schedules. This approach is useful for computerized supervision of large-sized PDP systems, as milestone scheduling can be fully automated. To add value to this discussion, the closely and the loosely coupled approaches are finally compared. System designers have accordingly the chance to easily identify advantages and disadvantages of both approaches.

Section 5.3 emphasises the generic problems solved with the proposed concepts. The question is answered how a management system can be set on top of an unchangeable production system. Important aspects are the coupling method of the communication between both systems and that robust interfaces are established. In case of a distributed production system a centralised management system can be of advantage.

Chapter 6

Practical research – description of the prototype

Chapter objective

> In this research project a major aim is to gather experience in the area of periodic data production management systems. The contribution described in this chapter is the prototype of such a system. It was developed and implemented for computerized supervision of a real-world periodic data production system in the market research organisation GfK Marketing Services. This prototype is based upon the model suggested in this thesis as loosely coupled approach. The system design concept used describes how established objects of project management, such as milestones, can be enhanced for the automation of recurring production planning activities. It additionally describes how suitable time management can be introduced by showing data flow dependencies. Several user interfaces for different user groups have already been implemented. They are described for providing an overview of how periodic data production management can be carried out with IT-support and to show its advantages. Prototyping is an iterative methodology. The prototype serves as a case study for this project and is consequently part of the evaluation of this research. Lessons learned during prototyping are summarised.

6 Practical research – description of the prototype

6.1 Introduction

The aim in this research is not only to discuss theoretical approaches, but also to test PDPM systems based upon the designed system concepts in practice. This is to contribute experience in this research area. Further reasons for choosing the prototyping activity are the advantage of an iterative development process to successively establish the most important features and to recognise and avoid dead-ends early. In this chapter, the prototype of a PDPM system is described which was developed for the real-world PDP system of GfK Marketing Services' retail audit panel production (cp. appendix B). The prototyped PDPM system covers three-quarters of this workflow for two out of sixty participating countries, up to date. The workflow's last quarter was not completed during this research project due to a simultaneous reorganisation of the production components. Although the prototype does not cover the whole workflow, the computerized time management for these business processes can be explained in detail. Moreover, the implemented prototype focuses rather on time management than on resource or cost management. This is why the provided description concentrates on aspects relevant for time management. The prototype is used as a case study and consequently contributes evaluation results to this research. This chapter presents the outcomes of the case study evaluations.

The reasons for the decision in favour of the loosely coupled approach (cp. section 5.2.3), as system design concept for the prototype, are explained in section 6.2. The decision to implement this approach reflects the available PDP infrastructure and the preferences of the management board in GfK Marketing Services as well as the advantages of it for large PDPs and its high automation level. Section 6.3 looks into the detailed concept of the prototyped PDPM system. It is discussed how the concept has been implemented for this prototype. An explanation follows how this PDPM system has been integrated into the PDP system environment. The objects, such as checkpoints and milestones, used for this purpose and the created user interfaces are explained. Additionally, background functions for prototype automation are presented. Section 6.4 evaluates how robust the prototype is against changes of milestones, their dimensions, connections and checkpoints. Problems emerged during prototyping are outlined in section 6.5. Consequently, the aspects are described which have been improved during

prototyping. This critical reflection completes the portray of the in industry prototyped PDPM system.

6.2   Reasons for using the loosely coupled approach

The possible system design concepts for PDPM have been discussed with GfK Marketing Services management. The result was the agreement for the loosely coupled approach (cp. section 5.2.3). The prototyped PDPM system has thus been based on this concept. The reasons which finally led to this decision are outlined in this section for GfK Marketing Services requirements in relation to their PDPM system.

A possible implementation of one of the candidate approaches, the closely coupled approach or the loosely coupled approach (cp. section 5.2), has been seriously discussed. The following summarised arguments were crucial for the decision in favour of the latter approach:

C1:   Time management should be standardised for all workflow participants (i.e. integration of international production planning).

This is supported in both candidate approaches. Production planning is more advanced when using the closely coupled approach and the degree of optimisation has been estimated to be higher.

C2:   The PDPM system should show the data flow for providing international transparency rather than showing the dependencies of jobs. The reason is that the content of data packages and its dependencies to others is of more interest in this business. Processing the jobs is the automated technical support to achieve this.

Job flow dependencies are focused in the closely coupled approach, whereas data flow dependencies are the strength in the loosely coupled case. Thus, the loosely coupled approach was preferred regarding to this point.

C3:   A high automation degree of PDPM should be achieved. Human resources should not be distracted from production itself. As human resources are cost-intensive the PDPM system should be automated as much as possible. In addition, the sheer amount of data packages produced each day underlines the need for replacing manual with automated PDPM procedures.

In the closely coupled approach planners are necessary to overcome the limits of scheduling algorithms. In contrast, the loosely coupled approach can be almost

fully automated.

C4: The PDP system should not be disrupted or interrupted by the PDPM system, because PDP is the core business where delays are not acceptable.

The PDP system is only allowed to run independently in the loosely coupled approach. This is due to the release-ready mechanism of the closely coupled method. The closely coupled approach implies that the PDP and the PDPM system are tightly coupled as the PDPM system releases production jobs whereas the PDP system informs the PDPM system about jobs which are ready. The risk is to delay PDP through this coupling approach.

C5: Production problems should be immediately identifiable (i.e. prompt identification of production errors or even production delays).

This is supported in both candidate approaches.

C6: Relevant key performance indicators and production overviews should be available to each time without manual effort.

This is supported in both candidate approaches.

The decision for GfK Marketing Services was to use the loosely coupled approach as the main argument, not to risk a disruption of the PDP system was the determining factor. However, both candidate approaches would have been possible. The decision in industry for a suitable system design concept depends highly on the application case. The above mentioned arguments are an example of the main factors that have led to the final decision in this case. This decision might differ in other cases. The determining factors have consequently to be individually investigated for each single case.

6.3 Detailed concept of the loosely coupled prototype

Up to this point, relevant system design concepts have been theoretically discussed. From now on, implementation results are presented, achieved by prototyping a PDPM system at GfK Marketing Services for the computerised supervision of a real-world PDP system. In this section the concept of this prototype and its implementation results are introduced in detail. This description contributes evaluation results on this research regarding how PDPM systems which are based on the proposed concept can look like, how they can be implemented and whether the concepts are useful.

The chosen loosely coupled approach implies that important points in the workflow have to be defined, the so-called *checkpoints*. How the prototyped PDPM system has been integrated into GfK Marketing Services environment and where checkpoints have been defined is introduced in section 6.3.1. In section 6.3.2, the layout of the prototype in relation to the *checkpoints*, *milestones* and *their dimensions* are described. The content-awareness of milestones is demonstrated on this real-world example. These design details are described for a better understanding of the user interfaces provided in the next sub-sections. User groups of the PDPM system with different interests have to be divided. This is because the focus of management differs from the focus of production operators regarding PDPM. These differences are described in section 6.3.3. A detailed overview of implemented user interfaces is provided in section 6.3.4. These GUIs offer sophisticated possibilities to supervise PDP world-wide, as all these tools are based on web technologies. Finally, it is depicted how this prototype has been automated. Milestones are created and maintained without user interactions. Consequently, production operators can concentrate on their daily core business, the PDP, and are not disrupted by PDPM except when needed. In section 6.3.5 an overview is provided of how the modules for automated milestone creation and maintenance are designed. Section 6.3.6 discusses the technology used for developing the prototype application and provides information about the resource capacities which were necessary for this development work.

6.3.1 Integration of periodic data production management into the environment

This PDPM prototype was planned to supervise the whole PDP workflow within the system environment of GfK Marketing Services (see detailed description in appendix B). In this section an overview is provided of how the PDP system's workflow and the elements necessary for PDPM were brought together.

<u>Data acquisition (see figure 6.1)</u>

Checkpoints are central elements in this approach. They represent points of interest in the workflow. These checkpoints are important because exactly at these points (and only at these points) status information of the production progress is provided. Thus, it was necessary that all PDP participants agreed to the definition of the checkpoints in the PDP workflow. In the following these checkpoints (i.e. CPx) and other relevant elements of the PDPM system are introduced for the company-specific workflow segments introduced in appendix B.2.
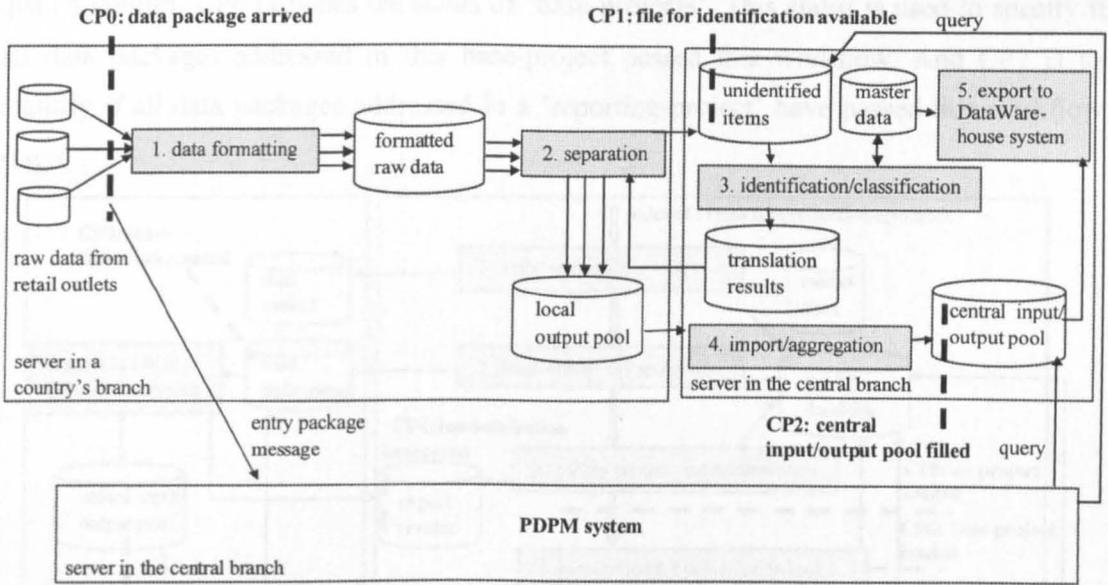
Figure 6.1: Checkpoints in the data acquisition system

CP0: The first checkpoint is to note if a new data package arrives at the system's entrance. As the entrances of this PDP system are distributed in the country branches (cp. section 1.2.1) the PDPM needs to be informed about this event by sending an asynchronous message that 'data entry packages' have arrived.

CP1: For each data package a so-called 'FFI – file for identification' is created and sent to the central branch. These FFIs contain unidentified items. In the case that all items of a data package can be identified, the corresponding FFI is empty. In each case, all data packages available cross this checkpoint and the arrival of these FFIs can be easily measured.

CP2: The arrival of a data package in the central output pool is documented with this checkpoint.

Reporting (see figure 6.2)

CP3: The checkpoint informs whether the order to export data packages from the data acquisition system was sent. In this case the 'load-definition' would be created.

CP4: The successful import of data packages from the data acquisition system into the Data-Warehouse system is documented if this checkpoint was passed. The load-definition is then executed.

CP5, CP6, CP7: The Data-Warehouse system works with specific data aggregations which are in this workflow called 'projects'. However, these are not projects as defined in PM. They are just groupings of data descriptions. Thus, CP5 informs whether

data packages pass the workflow corresponding to 'qc-projects'. This specifies the end of quality control. CP6 provides the status of 'base-projects'. This status is used to specify if all data packages addressed in this base-project passed this workflow. And CP7 is to identify if all data packages addressed in a 'reporting-project' have passed this workflow stage.
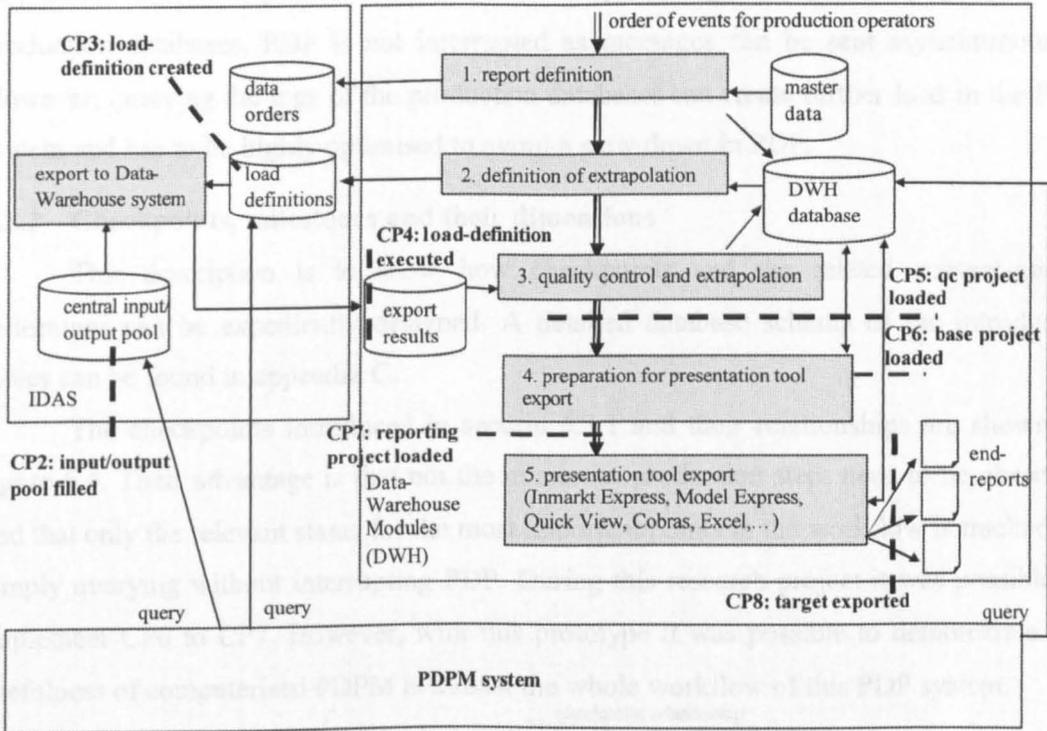
Figure 6.2: Checkpoints in the Data-Warehouse workflow

CP8: The successful creation of the presentation tool export is documented in this checkpoint. It is said the 'target file' is exported.

Distribution (see figure 6.3)
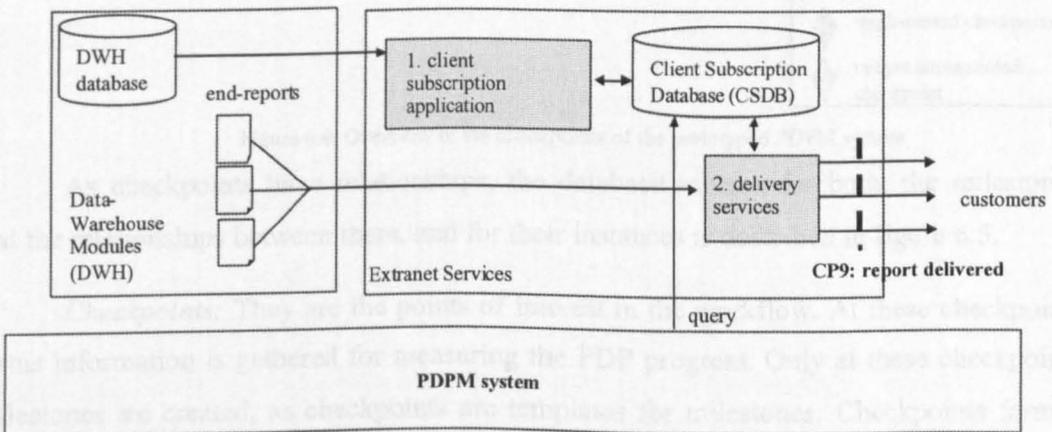
Figure 6.3: Checkpoints of the Extranet Services

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CP9: If reports are delivered to customers this checkpoint is passed. Electronic deliveries can be measured without user interactions. Manual deliveries need user confirmations.

All essential points of interest are documented in checkpoints. Measuring the status of production at these points can be done either by sending messages or by querying the production databases. PDP is not interrupted as messages can be sent asynchronously. However, querying the logs of the production databases can create further load in the PDP system and has to be highly optimised to avoid a slow-down in PDP.

6.3.2 Checkpoints, milestones and their dimensions

This description is to show how checkpoints and the related content-aware milestones can be expediently designed. A detailed database schema of the introduced tables can be found in appendix C.

The checkpoints introduced in section 6.3.1 and their relationships are shown in figure 6.4. Their advantage is that not the numerous production steps need to be observed and that only the relevant status for the most important points in the workflow is tracked by simply querying without interrupting PDP. During this research project it was possible to implement CP0 to CP7. However, with this prototype it was possible to demonstrate the usefulness of computerised PDPM at almost the whole workflow of this PDP system.
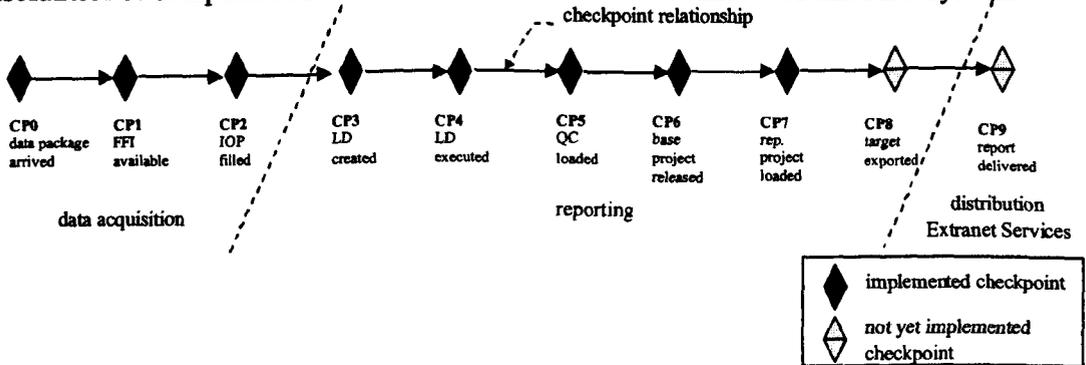
Figure 6.4: Overview of the checkpoints of the prototyped PDPM system

As checkpoints have relationships, the database schema for both, the milestones and the relationships between them, and for their instances is described in figure 6.5.

Checkpoints: They are the points of interest in the workflow. At these checkpoints status information is gathered for measuring the PDP progress. Only at these checkpoints milestones are created, as checkpoints are templates for milestones. Checkpoints form a chronological order for the status tracking. Milestones are only allowed at checkpoints. Checkpoints define the *dimensions* (i.e. product identifiers) observed at these points.

Figure 6.5 schema:

attributes: name, milestone dimension flags (see table 6.1) — checkpoints — id of predecessor / id of successor → checkpoint relationships — **templates**

attributes: id, cp-id, due date, status flags, dimensions... — milestones — id of predecessor / id of successor → milestone relationships — **instances**
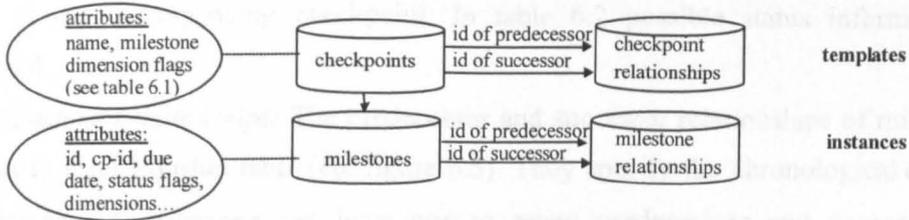
Figure 6.5: Database schema of the prototyped PDPM system

The dimensions observed for this prototype are described in table 6.1. The change in product identification can be seen in this table. For example, the dimensions in checkpoint CP2 are delivery type (i.e. specifies the retailer that has delivered data), delivery period (e.g. monthly), and the product-group (e.g. colour-TVs). The product identification changes in checkpoint CP3 to the reporting period (e.g. weekly) and the dimension 'project (i.e. aggregation of data packages). This change has to be handled cleverly by querying exactly the combination of the dimensions of both checkpoints, when creating the milestone relationships. Thus, checkpoints are only allowed where querying the relationships is possible.

dimension	CP0	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9
delivery type	X	X	X							
delivery period	X	X	X							
product-group			X			X	X	X		
reporting period				X	X	X	X	X		
project				X	X	X	X	X		
report profile									X	X
client period									X	X
client									X	X

Table 6.1: Checkpoint and milestone dimensions

Checkpoint relationships: The predecessor and successor relationships of checkpoints are stored in a relationship table (cp. figure 6.5). They specify the chronological order of the checkpoints. Possible are bifurcations and loops. However, in this prototype these structures were not necessary.

status	description
active	a milestone is active when one of its predecessors has progressed beyond 0%.
complete	a milestone is complete when its progress = 100%.
manual complete	the user can manually assign the milestone to being 'complete'. If so, the 'manual' status flag is set.
ignore	if a milestone is ignored, it is not considered in any statistic. This is for example done with 'test data'.
checked	a user can set this status for a milestone if the user has proven its status.

Table 6.2: Status information of a milestone

Milestones: A milestone has a due date, a completion degree, a country identifier and dimensions as specified in the corresponding checkpoint (see table 6.1). In contrast to checkpoints, this is not the definition of dimensions, but these dimensions relate to the data packages' content. For example, a milestone at CP2 can be related to the following content: Its delivery type is 'Sony', the delivery period is 'Jan-2005' and its product group is 'Color TVs'. Thus, milestones are content-aware. They show the status of a data

package at the corresponding checkpoint. In table 6.2 possible status information is summarised.

Milestone relationships: The predecessor and successor relationships of milestones are stored in a relationship table (cp. figure 6.5). They specify the chronological order of the milestones. A milestone can have one to many predecessors and successors. In addition, it is stored if a relationship between milestones is only planned or if it was actually processed. Planned and actual relationships are divided to meet the concerns of deviations which emerge during run-time.

6.3.3 Interested user groups

The many functionalities of a PDPM system raise the question whether user interests differ when using a PDPM system. Accordingly, a rough categorisation of user groups is advantageous.

For identification of the diverse users interests the following categorisation was created during this research project. User for PDPM can be categorised in higher management, production management, production operators and administrators. In the following a brief description of their different interests in relation to PDPM are outlined:

Higher management: The management board focuses on getting aggregated production overviews. Usually, this user group is interested in key performance indicators to roughly estimate whether the production performance is sufficient. This group is mainly interested to overview the whole production workflow. Often internationalised or summarised information about production are relevant. Optimisation potential or workflow segments which need improvements are of interest. The aim of these users is to represent the company in the public world or to delegate necessary improvements based on substantiated numbers.

Production management: Users which are responsible for specific workflow segments are referred to as production managers. They are interested in getting key performance indicators of their specific workflow segments. For identifying possible improvements they are often also interested to query details. Usually, the overview on the milestone level is sufficient. Exception reports are a requirement. Job details are not of interest. PDPM information is mainly used to inform higher management or to control production operators related to the workflow segment.

Production operators: The staff members which are responsible for carrying out production are characterised here as production operators. They are mainly interested in

activating job processing or the relevant user interactions for completing production jobs. They are also concerned to find production errors and to stabilise the PDP system's health. As their jobs rely often on jobs processed in previous workflow segments beyond their control they also take care of information about delayed jobs at the milestone level. A ranking of delayed milestones in their own responsibility will help to identify the most relevant problems. To cope with the sheer amount of information they mainly desire exception reports.

Administrators: The technical staff members which are responsible for system health and system performance are administrators. The programmers of the production steps belong to this group as they have to maintain the production step programs. All are interested in PDP system health and performance, but also in production errors which are related to technical problems.

The prototyped PDPM system can cover all the described user interests. Due to the differences in interests it is useful to specialise the PDPM user interfaces to the different users needs.

6.3.4 Overview of user interfaces

The relevant user interfaces of the prototyped PDPM system created during this research project are described in this section. Sophisticated information about PDP is provided for different user groups. The advantages of these GUIs are to quickly gain overview of future, current and past PDP processes in different aggregation levels on the basis of the milestone schedule. To support rapid production, the concepts of exception reporting have been considered by providing problem lists. The time-consuming task of planning production in traditional productions is in this PDPM prototype reduced to just an initial calibration of the milestone's due dates. Accordingly, the GUIs highlight different aspects to control production and help to save human resources.

In section 6.3.4.1 the user interface for milestone administration is introduced. This user interface can be used to query all milestones of future, current and past production periods. Predecessors and successors are shown in a very convenient way, as fast navigation through the whole milestone chains is provided. Advanced filters allow to query different workflow segments, specific milestone status information (e.g. delays) and milestone dimensions for supporting a precise search process to find quickly the relevant information.

The 'Rule-Administration' is a specialised user interface for creation and

maintenance of rules for the milestones due dates. These due date rules and their administration are demonstrated in section 6.3.4.2.

The identification of production problems can be divided in production error notification and problems related to production delays. As the focus in this thesis is time management, only the user interface for identifying production delays is introduced in section 6.3.4.3. This user interface visualises sophisticated problem lists based on milestone information.

How the production progress can be measured to inform management with relevant key performance indicators accordingly, is explained in section 6.3.4.4. This is presented on the example of the adherence of due dates for PDP in sophisticated diagrams.

6.3.4.1   The Milestone-Administration

In this section a detailed insight into the main user interface for this sophisticated PDPM system is given. The so-called *Milestone-Administration* is the implemented user interface created for GfK Marketing Services. The Milestone-Administration is a web-based tool used for the management of the milestones in PDP.
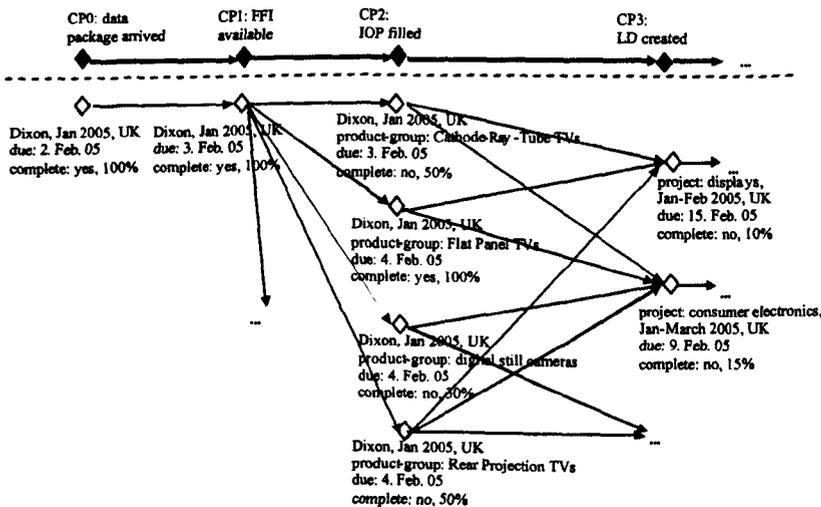
Figure 6.6: Problem of displaying milestones as net plan demonstrated with the prototype

One of the major problems with net plans is that they become quickly complex and unmanageable if a certain size is exceeded. This is not different for the milestones used in the loosely coupled approach (e.g. see figure 6.6). Designing a user interface for displaying thousands of milestones each with up to hundreds of predecessors and successors is difficult. The Milestone-Administration implemented within the scope of this prototype uses a compromise to cope with this problem. The compromise is to focus only on one milestone for displaying predecessors and successors. This is to show always a list of milestones where only the first five are displayed (see figure 6.7). A user can browse

through this list. Each time only one out of these five displayed milestones is selected. Only for this single milestone a list of its predecessors and a list of its successors is displayed. By using this milestones' predecessor and successor relationships (i.e. clicking on it), the user can quickly navigate through the whole production process.

In the following the different elements of this user interface presented in figure 6.7 are explained:
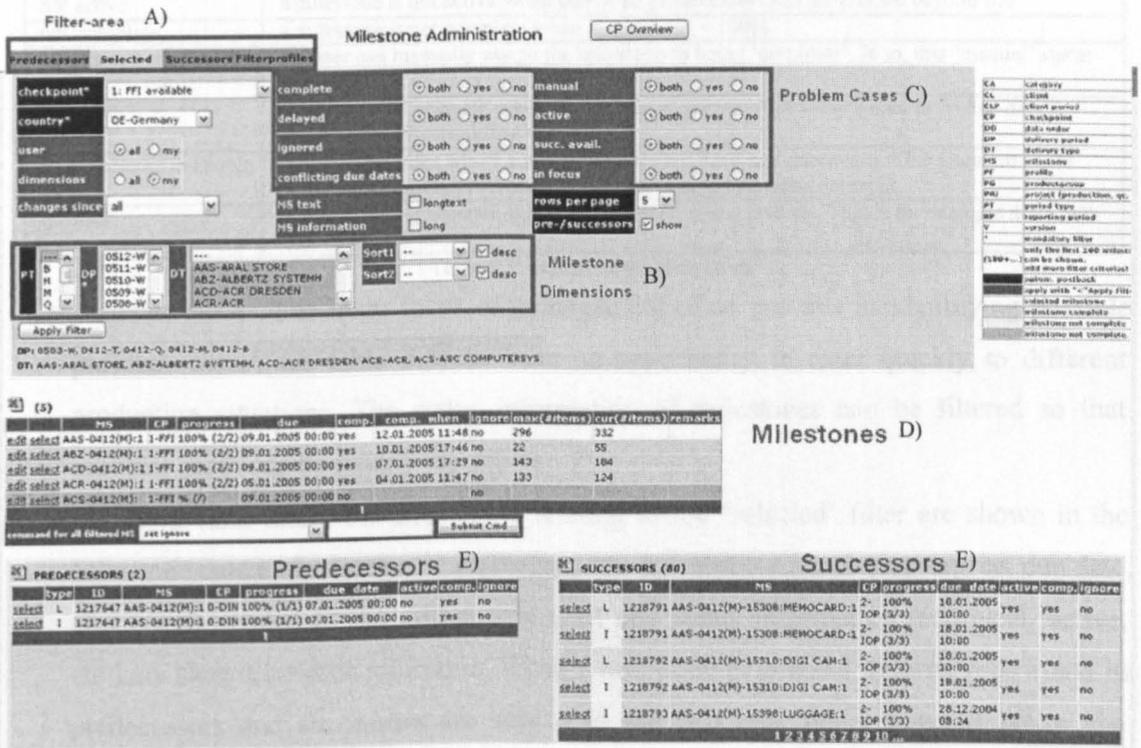
Figure 6.7: The Milestone-Administration user interface

A) *Filter area:* Detailed filters offer the possibility to search for and view specific milestones. To simplify filtering, the user can store filter settings and thus save time. Filters can be applied to milestones belonging to a certain checkpoint and to the selected milestone's predecessors and successors. The filters are powerful enough to allow a great deal of flexibility. There are three filter areas accessible:

- Selected: Used to get a list of milestones belonging to a checkpoint.
- Predecessors: Filters the predecessors of the selected milestone.
- Successors: Filters the successors of the selected milestone.

B) *Milestone dimensions:* All milestone dimensions can be filtered by allowing the user to view what they are primarily most interested in. Milestone dimensions correlate to the product identifiers of the observed data packages. Accordingly, dimensions are highly dependent on the specific production process which has to be supervised. They are only

meaningful for production operators which are familiar with this specific data production. Examples in the screenshot of figure 6.7 are:

- PT= Period Type: Specifies if periods are monthly, bimonthly, weekly etc.
- DP= Delivery periods: Periods for delivered data packages (e.g. 'Jan 05').
- DT= Delivery types: Specifies the retailer which delivers data (e.g. 'Dixons').

status	description
not active	a milestone is not active when non of its predecessors has progressed beyond 0%
not complete	a milestone is not complete when its progress < 100%
not manual complete	the user can manually assign the milestone to being 'complete'. If so, this 'manual' status flag is set.
delayed	a milestone is 'delayed' when its due date is greater than today's date or its due date is greater than its completion date.
no successors available	there can be cases where a milestone does not have any successors. This situation could potentially point to problems in the process or to open data potential.
ignored	if a milestone is ignored, it is not considered in any statistic. This is for example done with 'test data'

Table 6.3: Milestone problem cases

C) *Problem cases:* The main focus of management often prevails in identifying possible problem cases (see table 6.3) to have an opportunity to react quickly to different production situations. The status information of milestones can be filtered so that problem cases can be readily identified.

D) *Milestone data table:* All milestones relating to the 'selected' filter are shown in the Milestone data table. Each row represents one milestone. Completion degree, due date, dimensions (coded in the milestone's text) and status information (complete, active, etc.) are shown for each milestone. When a milestone is selected, it turns yellow and its predecessors and successors are shown in the two data tables situated below the Milestone data table.

E) *Predecessors/successors data table:* The predecessors/successors of the selected milestone are shown in this table. The list can be filtered using the predecessors/successors filter area. If a relationship to a predecessor/successor was only planned then this is specified with an 'I' (i.e. initial connection). If the relationship was actually produced then this is shown with an 'L' (i.e. latest connection).

The milestones are colour-coded. A delayed and not completed milestone is displayed in red, completed milestones are displayed in green and not completed but not delayed milestones are colour-coded in grey. Thus, users can quickly identify problem cases by just considering the colours of the milestones. Users with access rights can update the status information of milestones. They can set milestones manually to complete, ignored, checked or they can change its calculated due date.

This user interface is mainly of interest for production operators and production

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management. The information offered is much too detailed for higher management. This user-interface offers a complete insight in the whole production chain of the PDP process at GfK Marketing Services. It is a standardised PDPM tool that operates world-wide. Navigation through the international process is possible. Milestones inform cleverly about delays or success in production. User can filter the most interesting information or intervene into the process by updating status information.

6.3.4.2 The Rule-Administration

PDP is a highly repetitive business. To take advantage out of this fact, the planning of the milestones' due dates is based on rules as explained in section 5.2.3. Thus, planners are not necessary, as rule creation is only an initial task. In this section, the administration of these rules for due date management is outlined. The user interface called *Rule-Administration* is introduced.

Figure 6.8: The Rule-Administration user interface

The advantage of using rules for due data planning is that these rules only have to be manually planned once when new data packages complement production (e.g. a new retailer delivers data) or if rules need to be changed because of production rearrangements. Once established, the rules are used to automatically calculate the exact due dates of milestones. Each production period the automated calculation is used to assign a due date to a milestone which is relevant in this period.

The due date rules are assigned to each checkpoint. They are used to determine planned due dates of milestones. A 'planned due date' is the date on which the milestone is expected to be completed. For example, a rule could say:

The planned due date for all milestones in checkpoint 1 related to the product-group 'Colour TVs' is one month after the delivery period.

Rules can be general, or specific. For example, an *exception rule* can exist which is only

relevant during the Christmas period:

> *The planned due date for all milestones in checkpoint 3 related to the reporting*
> *period December 2004 is the 2nd of January 2005.*

A rule can also apply to a specific retailer, for example, 'Media Markt':

> *The planned due date for all milestones in checkpoint 0 that relate to the retailer*
> *'Media Markt' is the 4th day of the month directly after the delivery period.*

As demonstrated on these rule examples, this concept offers strong planning possibilities. The introduction of rules to the PDPM system is organised via the Rule-Administration tool (see figure 6.8). Rules can be created, modified and deleted with this tool.

Users of the Rule-Administration are production operators. Only this user group knows exactly what is planned and what specific or general rules are. The rules are organised in a hierarchy. A so-called 'rule sequence' identifies if a rule is a specific or a general rule. The more dimensions of milestones are assigned to a rule the more specific is the rule. Thus, international standardised planning is possible and is reduced to a minimum of manual effort.

6.3.4.3 Production problem identification

One of the main problems in PDP is that the sheer amount of produced data is overwhelming and that it is usually not easy to keep the overview of all data packages which are currently produced. The workflow of the prototype environment is furthermore distributed. This fact complicates the tracking as different working groups are affected. As explained in section 4.2.4 and in section 5.2.3 it is therefore good practice in PDP to focus mainly on exceptions. The IT-support for the possibility to concentrate on the few remaining problems is thus a need. In this section, a user interface for identifying these remaining production problems is introduced. Statistics and lists on the base of milestones can be queried according to production needs.

In the following the example of a problem list is introduced that has been implemented during this research project. This example and all other implemented lists are based on querying the milestone table and answer different questions in relation to milestone states. The user interface implemented is called *Milestone-Statistics*. A user can choose the required list in the drop down box 'report' (see figure 6.9). Filters for focusing on specific milestones are available. Thus, users are able to query the checkpoints, countries and milestone dimensions which are of interest for them. In a table below the

filters, a list of resulting milestones is provided. Each row in this list represents a milestone that belongs to the problem case queried.

Aposteriori Milestones Statistics [CP Overview]

checkpoint*	3: LD created
country	DE-Germany
report	ranking for delayed not completed
conn. type	⊙ both ○ initial ○ latest
in focus	○ both ⊙ yes ○ no
MS information	☐ long
MS text	☑ longtext
dimensions	**RepPeriod** ··· Dec05-Mar06 Sep05-Feb06 Nov05-Feb06 Feb05-Jan06 Aug05-Jan06 Oct05-Jan06 **Project** ··· 1788 -ZZ- Electro Specialists 1mtl-PP 1792 DE- SDA monthly (12.8.02)-PP 1793 -DE- SDA 2 mtl. (12.8.02)-PP 1794 -DE- CE monthly (12.8.02)-PP 1795 -DE- CE xx 2monthly (12.8.02)-PP 1834 DE- Test-ProductionProject-PP **Sort1** ranking
	[Apply Filter]

Focus: 100 days
RepPeriod: Oct05

📄 (5)

	ranking	delay in days	MS	CP	progress	due	comp.	comp. when	ignore	checked	remarks
edit	1	10.10	[32204] DE- PROD SDA IB.IR 1m Draught Systems-Oct05	3-LDC	0% (0/1)	04.11.2005 14:59	no		no	no	
edit	2	0.10	[18847] DE- PROD CE Standard 1 m 1 Gruppe-Oct05	3-LDC	0% (0/1)	14.11.2005 14:59	no		no	no	
edit	2	0.10	[18860] DE- PROD CE Standard 1 m 2 Gruppe-Oct05	3-LDC	0% (0/1)	14.11.2005 14:59	no		no	no	
edit	2	0.10	[18869] DE- PROD CE Standard 1 m 3 Gruppe-Oct05	3-LDC	0% (0/1)	14.11.2005 14:59	no		no	no	
edit	2	0.10	[4969] DE- PROD CE Standard 1m-Oct05	3-LDC	0% (0/1)	14.11.2005 14:59	no		no	no	

Figure 6.9: Milestone-Statistics - ranking for delayed not completed milestones

Problem list - ranking for delayed and not completed milestones: This list is a ranking of milestones which are delayed and not completed. The list is a ranking because the most urgent cases are shown first. In the example presented in figure 6.9, five milestones of the German branch are presented in the list that are all delayed. The milestones belong to checkpoint CP3. The first milestone indicates that a project, related to data of 'SDA-small domestic appliances-draught systems', has been due at '4. Nov. 2005 2:59 p.m.'. The due date is interrelated to the monthly reporting period of this milestone ('Oct05'). The milestone is more than 10 days delayed. Its progress is 0%. It has not been manual completed, ignored or checked. Thus, this milestone is a relevant problem case and needs further user examination.

Other problem lists which have been implemented, yet, are not presented in detail, but are mentioned for gaining an impression of the great possibilities that they can offer:

- *List for delayed and not completed milestones with successors*
- *List for delayed and not completed milestones but predecessor complete*
- *Success list – ranking for delayed and completed milestones*
- *List that indicates open data potential - no successors*
- *The 'green' working list – completed milestones and all predecessors complete*
- *The 'red' working list – at least one predecessor not complete*

On the example of this user interface it is demonstrated how expressive the evaluation of the milestone states can be. The whole data flow can be tracked and evaluated with these sophisticated lists. However, these lists do not show predecessors or successors of milestones. If users want to see them they only need to click on a milestone's text as this is a link to the Milestone-Administration user interface. The Milestone-Administration opens and filters the specified milestone with its predecessors and successors accordingly.

It is possible to query in the Milestone-Statistics very specific production information on an exceptional base. World-wide and effortless querying on problem cases, examples for successful production and on working lists is possible. Moreover, this user interface is very flexible. For example, it is possible to integrate very easily new problem lists if required.

6.3.4.4   Production progress measurement

Important for managing a company successfully are management overviews that fit to the business. As explained in section 2.3.4 it is possible to interpret key performance indicators form traditional goods production and to use them in PDP. In this section, the management of due date adherence with the prototype is introduced. The related user interface is called *Production-Progress*, because due date adherence can be used to measure the production progress. The reason is, less delays in production raise the progress. This user-interface is provided for production management and higher management and is outlined to demonstrate the possibilities gained with the prototype.

For the measurement of milestone delays, a background process has been developed that stores each night the delays of milestones which have been due in the last 90 days. This allows to show a reliable 'window' of the milestone development by exclusion of antiquated information. This meets the concerns of this continuous business. In particular, the numbers of milestones are measured that belong to the states:

- Complete and not delayed
- Complete and delayed
- Not complete and not delayed
- Not complete and delayed

The four state combinations cover all milestones. Thus, each milestone belongs to one of these combinations. The corresponding user interface shows all calculations in relation to the combinations. This user interface is partitioned in four major areas. In the following the areas are described in more detail:
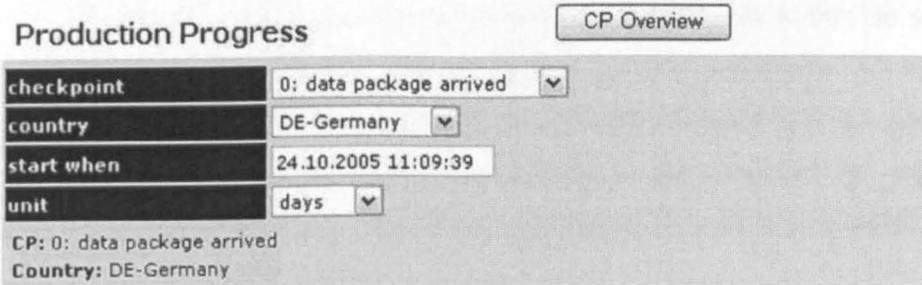
Figure 6.10: Available filter for production progress measurement

1. *The filter area* (see figure 6.10): A user can choose the checkpoint, the country (an international overview is also possible), the starting date of measurements and a unit (e.g. days, months, years).
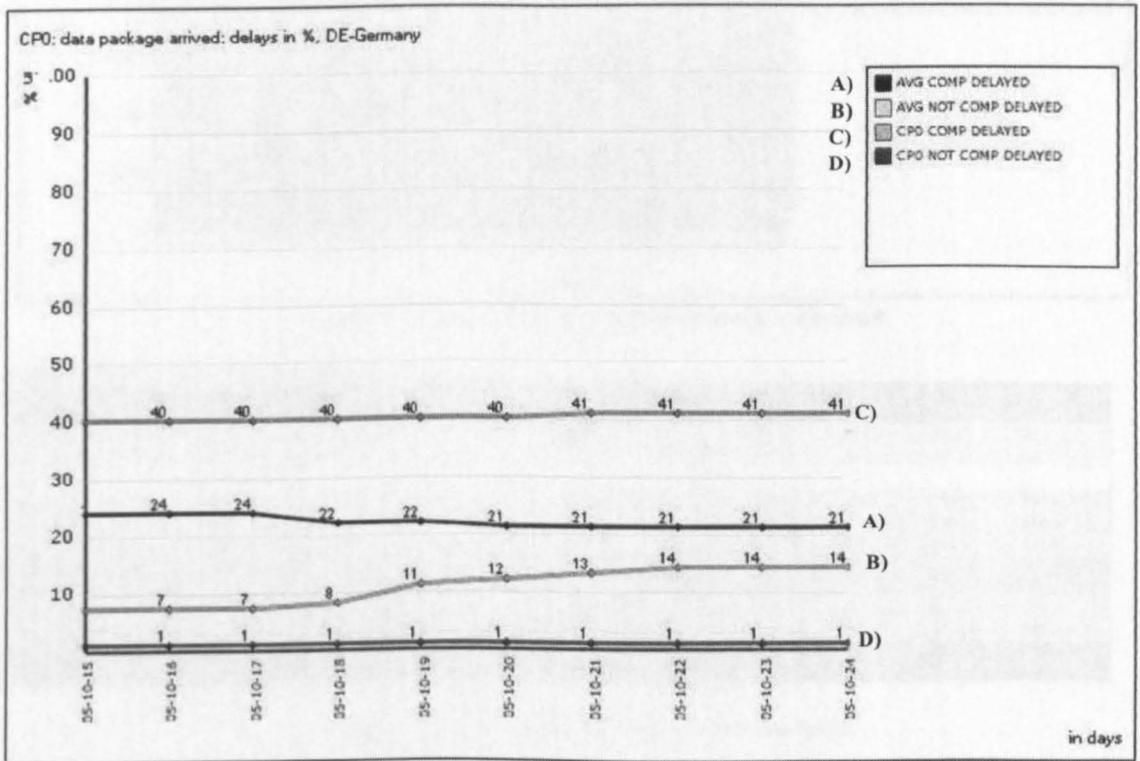
Figure 6.11: Diagram of production delays in percent at a specific checkpoint

2. *The diagram of production delays in percent* (see figure 6.11): This diagram presents the delays at a specific checkpoint. Values are presented that have been measured either as average over all checkpoints or for one specified checkpoint. Their differences demonstrate how production is delayed at this checkpoint in comparison to all production

delays. Each of the values is additionally divided into the measurement of related milestones that are complete and into the measurements of uncompleted milestones. In figure 6.11, an example is shown for checkpoint CP0 that illustrates for ten days the development of delays in the German production.

3. *The diagram of the due date adherence* (see figure 6.12): In this bar graph the numbers of milestones are presented that belong to a specific checkpoint. All four state combinations are shown for the chosen unit. In the example of figure 6.12 it is shown that a little less than half of the milestones are delayed in the measured ten days. This demonstrates expressively the high quantities of deviations that need to be handled only for Germany at their PDP system's entrance.

CP0 adherence of due dates, DE-Germany

A)	CP0 COMP NOT DELAYED
B)	CP0 COMP DELAYED
C)	CP0 NOT COMP NOT DELAYED
D)	CP0 NOT COMP DELAYED
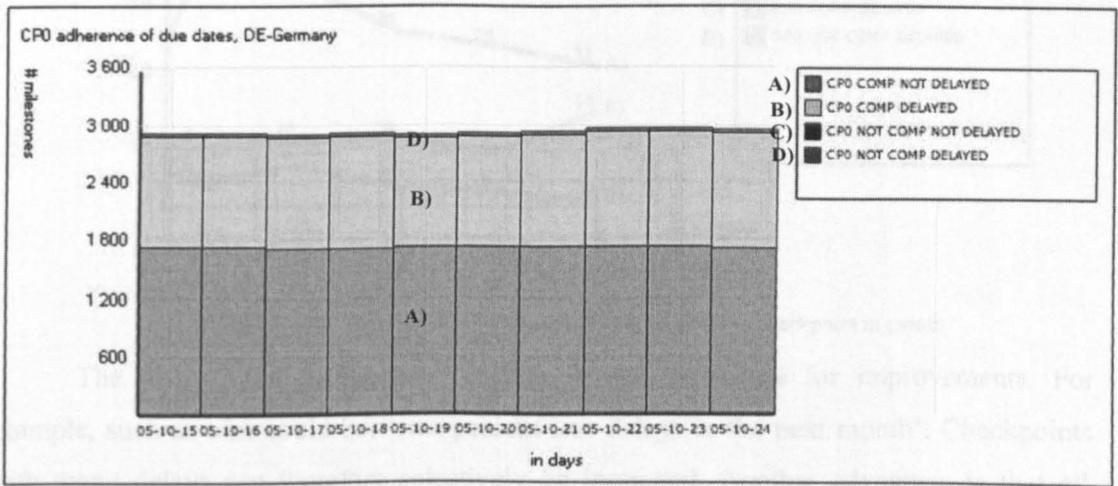
Figure 6.12: Diagram of the due dates adherence at a checkpoint

production delay per day (sum of last 90 days)

checkpoints	2005-10-15	2005-10-16	2005-10-17	2005-10-18	2005-10-19	2005-10-20	2005-10-21	2005-10-22	2005-10-23	2005-10-24
AVG COMP DELAY	24	24	24	22	22	21	21	21	21	21
AVG N COMP DELAY	7	7	7	8	11	12	13	14	14	14
CP0										
CP0 TOTAL	2895	2894	2879	2887	2884	2896	2915	2946	2946	2931
CP0 COMP N DELAY	1707	1707	1693	1692	1704	1699	1701	1701	1701	1689
CP0 COMP DELAY	1161	1160	1159	1163	1148	1164	1181	1211	1211	1208
CP0 COMP DELAY PERCENT	40	40	40	40	40	40	41	41	41	41
CP0 N COMP N DELAY	0	0	0	0	0	0	0	0	0	0
CP0 N COMP DELAY	27	27	27	32	32	33	33	34	34	34

Figure 6.13: Table of due date adherence at a checkpoint

4. *The table of the due date adherence* (see figure 6.13): This table contains all values presented in graphical form in the diagrams above. The values can be used for further differentiated analyses that users may want to do. They are presented for the same ten days that have been specified as unit. In the example of figure 6.13, the values of Germany for checkpoint CP0 are presented for all four state combinations as number of milestones and in percent. The average in percent of all milestones is also accessible.

The analysis of production progress is also possible on a monthly base. Each of the four provided areas shows in this case totals of the included months. The fluctuations are becoming clearer in the example provided in figure 6.14. Management should be informed accordingly.

CP0: data package arrived: delays in %, DE-Germany
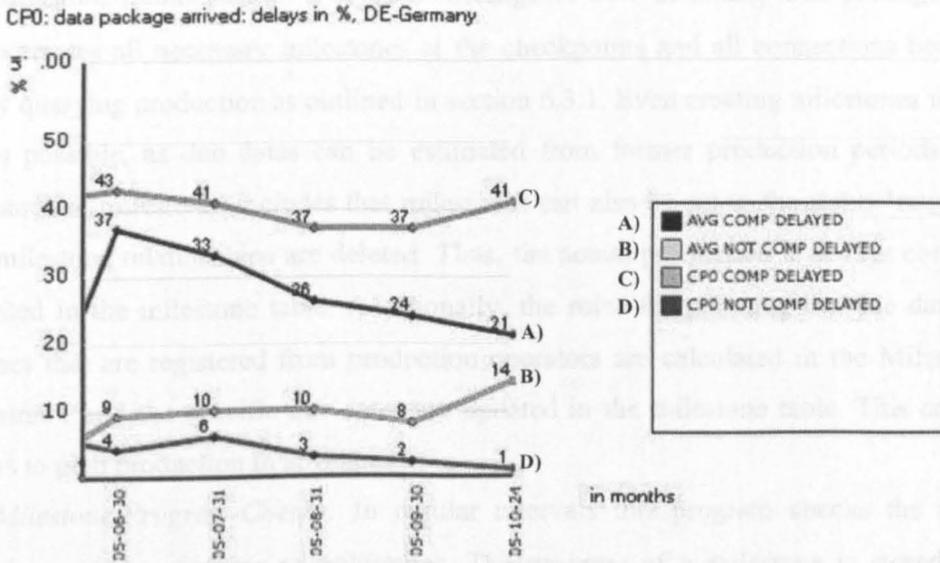
Figure 6.14: Diagram of production delays in percent at a checkpoint in month

The aim of the management can be to set guidelines for improvements. For example, such an aim could be: 'two percent less delays in the next month'. Checkpoints with many delays can therefore selectively be improved. Another advantage is that all participating country-branches use this standardised control tool. Identification of problems on a national and international base is thus easily achievable.

6.3.5 Automated creation and maintenance of milestones

A major advantage of the loosely coupled approach used for the prototype implementation is that the PDPM system can almost be fully automated (cp. section 5.2.3). The main modules that have been implemented for the prototype to establish this automation are published in (Schanzenberger & Lawrence, 2005, 9-11) and are introduced in this section. The advantage is, there is no need that users create or maintain milestones and accordingly they are not disrupted in their daily PDP business. PDPM needs no further (manual) activities to be available.
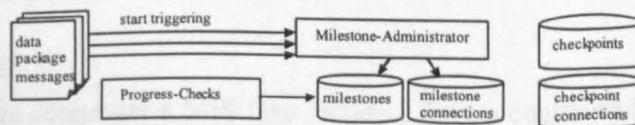
Figure 6.15: The main software modules for automating milestone creation and maintenance

In the case of the prototype, milestones are automatically created after start triggering. Messages sent from each country branch to the centralised PDPM system are necessary to inform about delivered data packages. Then, the fo llowing building blocks are used to create and maintain milestones (see figure 6.15):

Milestone-Administrator: For each message of new incoming data packages this program creates all necessary milestones at the checkpoints and all connections between them, by querying production as outlined in section 6.3.1. Even creating milestones for the future is possible, as due dates can be estimated from former production periods. The maintenance of milestones includes that milestones can also be set to the status 'removed' or that milestone relationships are deleted. Thus, the actual production is always correctly represented in the milestone table. Additionally, the rules for planning the due dates of milestones that are registered from production operators are calculated in the Milestone-Administrator and the specific due dates are updated in the milestone table. This enables operators to plan production in advance.

Milestone-Progress-Checks: In regular intervals this program checks the status information and the progress of milestones. The progress of a milestone is stored as a current and a maximal value in the milestone table (cp. appendix C). The maximal value used in the prototype is highly dependent on the checkpoint. This means per checkpoint milestones have different maximal values for progress measurement and must therefore be interpreted individually by the users. The current value is also dependent on the checkpoint and will be counted depending on the production situation. For example, the maximal value on the first checkpoint CP0 is 1 to state if a planned entry package is available. The corresponding current value states if the planned entry package is really available during the querying or not ('0: not available' or '1: available'). For each checkpoint a check-function has been implemented to enable uncoupled checking milestones' status.

6.3.6   Technology and development of the prototype

This section discusses the technology used in case of the prototyped PDPM system and presents some essential aspects of its development process. The purpose of this discussion is to investigate technical pre-conditions and to explore the time demand for possible PDPM system implementations in industry and in future.

The used technology

The PDPM system comprises a MIS (see section 2.2.4), a centralised database, and background functions (see section 6.3.5). The MIS consists of web pages with dynamic

database access due to the future-orientation of web technologies and the need for world-wide availability. Although other server script languages would be possible, in this case the web pages are written in ASP.NET from Microsoft (cp. Anderson et al., 2001) as this fits best into the environment of the company. The three-tier architecture is supported by a web server, a IIS (Internet Information Server) from Microsoft (Braginski & Powell, 1998) which was prior to prototyping already available. The database of the PDPM system, which is an Oracle 9.i database (Oracle Corporation, 2005), is centralised to ensure the world-wide access of all participating country branches. The advantage of using Oracle is that all background functions of the PDPM system could be written as stored procedures in PL/SQL (Tuerscher, 1997). This ensures quick database access and helps to support performance goals. However, every relational database system is possible for a PDPM system's implementation and background functions can just as well be implemented in any other programming language. The web pages and the web server run on fast personal computers. The database is outsourced to a third party vendor, runs on a Superdome server (HP Superdome Integrity, 2005) under Unix, and can be accessed via a 100 Mbit network.

This description leads the argument that the choice of software and hardware technologies for a PDPM system depends rather on the system's size, performance goals, and the availability of legacy technologies than on any restrictions due to the loosely coupled approach.

The development process

The prototype was analysed, designed, developed and implemented within a period of approximately two man years from the author of this thesis. Mainly two additional system developers implemented parts of the code by using the concepts designed from the author. Several system stakeholders, the management board of GfK Marketing Services, production operators, third party consultants and both PhD supervisors influenced the outcomes through fruitful discussions. The research in the background of the prototype has also been discussed in the research community at academic conferences. The development process was iteratively carried out as appropriate system design concepts, requirements, and system specifics where successively researched and extended to complement computerized PDPM. Initial tests with the prototype were carried out with potential users from the management and the operational level. Approximately thirty users from two countries participated on trainings which presented the user interfaces and tested sporadically the PDPM system. Roughly hundred man hours were thus spend on testing.

This thesis contributes to shorten development periods of future PDPM systems as proposed system design concepts can be used and the provided analysis offers decision support for system designers.

6.4 Adaptation capability of the prototype objects

The question what happens if the definitions of checkpoints, connections, milestones, or their dimensions are changed is discussed in this section. The investigation of the implemented prototype shows that objects such as milestones and their connections can easily be adapted as this belongs to the daily business in a dynamic PDP environment. Less flexible is the concept if milestone dimensions or checkpoints have to be changed as these are the indispensable basic elements for instantiating the milestones. However, apart from possibly necessary program modifications of the PDPM system the only risk is to loose the milestone history (see table 6.4). A loose of it means, past production periods cannot be queried anymore because the milestones' status information of the past periods is on a different level than the status information of new periods.

objects	alteration type	program modification of PDPM system			is there a chance to adjust (a part of) the milestone history?		loosing (a part of) the milestone history	
		altering filter in GUIs	altering object in background procedures	altering object in the object's table in the database	by using the milestone history itself	by using old periods of PDP data	object located at the beginning or the end of the object chain	object located in the middle of the object chain
milestones	adding	-	-	automated	-	x	-	-
	removing	-	-	automated	-	x	-	-
	changing	-	-	automated	-	x	-	-
milestone connections	adding	-	-	automated	-	x	-	-
	removing	-	-	automated	-	x	-	-
	changing	-	-	automated	-	x	-	-
milestone dimensions	adding	x	x	x	-	x	possible	possible
	removing	x	x	x	x	x	-	-
	changing	x	x	x	-	x	possible	possible
checkpoints	adding	-	x	x	-	x	-	possible
	removing	-	x	x	x	x	-	-
	changing	-	x	x	-	x	possible	possible
checkpoint connections	adding	-	x	x	-	x	possible	possible
	removing	-	x	x	x	x	-	-
	changing	-	x	x	-	x	possible	possible

-: no   x: yes

Table 6.4: Consequences of adapting implemented objects

Consequences of changing milestones and their connections: The evaluation shows that the loosely coupled approach is a very robust concept for large volumes of dynamic data. This means it does not matter whether and how many unknown data packages arrive at the data entrances as milestones will automatically be created or changed from the

background procedures. If production diverges from the original production plan, milestones and the connections between them are created or adjusted without manual effort. Changing milestones and connections is accordingly easy and highly automated.

Consequences of changing milestone dimensions: In cases where added or changed dimensions cannot be complemented or changed in the milestone history the danger is to loose it. However, this can be avoided if an added dimension can be complemented in all affected milestones of the history or if the changed dimension can as well be changed in all affected historical milestones. In addition, the milestone history is not affected if a dimension is removed as this can be done for all past and future periods together.

Consequences of changing checkpoints and their connections: Adding or removing a checkpoint at the end or at the beginning of the chain is never critical. In these cases the milestone history is not in danger because the milestones and their connections on these checkpoints will simply be available from a certain point in time or can directly be removed. However, it can be problematical if checkpoints are added in the middle of the checkpoint's chain. As milestones and connections of the past sometimes cannot easily be created from scratch the history can get lost because there might be a lack of connection to predecessor and successor milestones. In contrast removing a checkpoint in the middle of the chain is innocuous because the connections of the available predecessor and successor milestones can be used to reproduce the new checkpoint structure. Changing a milestone can mean either to change the dimensions of milestones (see discussion above) or to change the sequence (i.e. to change the connections between checkpoints). In the latter case the milestone history can get lost. The same can happen if new checkpoint connections are added. In both cases it is difficult to rebuild the connections in the milestone history.

It is noteworthy that adapting the milestone history correctly is only possible if a history of the master data and the periodical data is available. In case of the prototype the master data pool contains only currently valid data. The periodic data are available for some past periods. The consequence for the prototype is that the milestone history can be adjusted for these past periods and with respect to the master data only with some uncertainty.

Although to loose the milestone history is not enjoyable it is not a catastrophe. For example, it is usually possible to specify a past period from which on the changes are valid and to remove only former periods from the history. This saves at least a part of the history. In addition, the experience in practice shows that such changes do not happen very

often as changes usually are only necessary if the product identifiers of the data are changed or production steps are modified. As it has to be reflected in the PDP system as well as in the PDPM system this is accordingly avoided if possible.

6.5 Critical reflection of the prototype: problems, necessary iterations and improvements

The prototype of the PDPM system for GfK Marketing Services was improved in several iterations. The most relevant solved and open problems identified during prototyping are described in this section. This is to critically reflect on the experiences with the loosely coupled approach and to correspondingly contribute evaluation results. The emerged problems have been classified into functional problems, performance problems, amendments/scalability problems, prototype-related problems and social problems. They are described in the following to complete the picture.

1. *Functional problems:* In one of the early iterations of the prototype the due dates of milestones have been calculated from previous production periods. This so-called *history-due-date* has been evaluated as not strong enough due to the high number of fluctuations. Reasons for fluctuations are seasonal behaviour but also fluctuations due to PDP system development has been recognised. This problem has been solved by introducing the described due date rules (cp. section 6.3.4.2). Accordingly, a milestone can have a *history-due-date*, a *calculated due date* (i.e. derived from the rules), and a *data-order due date*. All three dates inform users exactly when data packages need to be completely processed.

A problem for the early prototype were the many exceptions in production. Thus, two new states have been introduced. The status 'ignored' is used to exclude data packages that are related to tests and nonrecurring production (i.e. loading back-data from previous production cycles). Moreover, data packages that relate to old production cycles have been excluded (e.g. considering valid-until dates in the queries). The status 'checked' is used to indicate that a delay has been recognized by staff. Although both status information are as much automatically updated as possible, this means production operators need to maintain the milestone states manually from time to time.

2. *Performance problems:* During this research project the milestones have been automatically created for two out of approximately sixty possible countries. The reason was performance problems that affect the PDP system, occurred when the PDPM system queried the production status information. This led to the fact that updating the world-wide

milestone information has been organised in short intervals (e.g. every second hour). Consequently, this decoupled prototype is not triggered by events, but polls frequently the production status information. The risk remains that production can be slowed down if querying production status is frequently polled. However, the following ideas and concepts have helped to reduce this problem. The queries in the prototype modules have been optimised. The optimised queries do not fetch all available data. Instead, only the changes in status information are queried. This reduces the queries to the current production. The past production remains unchanged. Thus, initial tests with the prototype at the end of this research project have shown that the prototype is prepared to work with the tenfold to twentyfold numbers of countries. Proposed further changes are code changes of production step programs, as they need to log the production changes instead of logging only the results in production. This will lead to a further effective reduction of the performance problem.

However, the evaluation of the loosely coupled approach is independent from the emerged performance problems of the prototype. Research in the database community shows that effective tuning mechanisms are available (e.g. database partitioning, indexing or optimising queries) and large-scaled systems in industry are still points of interest (e.g. Sion, 2005, 601-612). Therefore, it is assumed that initial problems can be fixed and performance can be achieved for the prototype and for any application in industry based on this concept.

3. *Amendment problems and scalability:* Once implemented, checkpoints, milestones and their dimensions are relatively static in case of the prototype. This means, once established changing these objects is possible, but tends to be complex (cp. section 6.4). Changing program code is usually required which is costly and resource consuming. Further research in this direction could investigate whether using variables instead of hard coded values could reduce this problem. Even worse is the possible consequence that a part of the milestone history can be lost. However, changes in these objects may only be needed in the case of necessary major changes in the PDP system's production steps. As those changes appear only occasionally they may be tolerable.

However, the scalability of the loosely coupled approach in relation to data volume and scope is open to future extensions due to its database-oriented design of milestones, checkpoints, and its relationships and thus underlines the relevance of this concept in industry.

4. *Organisational problems:* The checkpoints CP0 to CP7 have been implemented during this research project. However, the implementation of the last checkpoints CP8 to CP9 was not possible. The reasons have been an upcoming reorganisation of the PDP system in the mentioned workflow area. An additional shortage in human resources was the reason why these changes could not be finished in time. This led to the fact that using the prototype was restricted to the implemented checkpoints. The consequence was that users tested the PDPM system only rudimentarily. The feedback of the users in relation to the prototype has thus been with holding. The lack of completeness resulted also in the fact that it was not envisaged to measure a return on investment to the end of this research project.

Other problems related to the prototype have been that several iterations were necessary to show reliable production status information. Initial bugs in the PDPM modules have been removed. Some other problems occurred because the correct interpretation of the production data was not sufficiently documented. However, these problems have been solved.

5. *Social problems:* A major problem of this PDPM tool was that production operators did not want to be further controlled by any system. They feared consequences derived from the information and tended to keep their knowledge instead of sharing it. The management therefore needs to convince and motivate production operators to use and support this MIS. Time management is not only a control, but also a medium to help production operators in planning production accordingly. The effect which applying PDPM has onto the effectiveness of a PDPM systems is an important aspect and is further investigated and discussed in section 7.2.

In the case of this prototype, strong negotiations where necessary to agree on the checkpoints with all participating working groups. The working groups have different views about importance and details of checkpoints and dimensions. Accordingly, as always, compromises were necessary.

A further recognized problem was that users came into conflict with the level of details provided in the GUIs. Different interests have to be supported. Production overviews on high levels are required from management. Low level overviews are required for production operators. In several cases the overview provided with milestones was not detailed enough for production operators, as they often need information on the job level. The consequences during this research project have been that high level overviews have been provided on separate user interfaces and the detailed overviews have been based on

compromises on as much as possible in-depth production information. A possible solution could be to link (e.g. via hyperlink) the milestone overviews which include the product keys of the data packages to the log web pages that can present the related jobs. Production operators are then enabled to quickly change to the necessary detailed information sources.

6.6   Chapter summary

In this chapter a prototype of a PDPM system is introduced and evaluated. It is based on the loosely coupled approach introduced in chapter 5. The prototype has not been developed in a experimental laboratory. It was possible to implement the prototyped PDPM system in industry for computerized supervision of a very large PDP system. The company that prototyped the PDPM system in cooperation with this research project is GfK Marketing Services. Their PDP system is used to periodically produce various market reports from retail sales data that is delivered in regular intervals from retailers all over the world (cp. appendix B).

The reasons for choosing the loosely coupled approach for this prototype implementation are discussed in section 6.2. They are summarised in the following:

- Time management is in this approach standardised as PM has been used as metaphor. The advantage is PM techniques are proven and well known.

- Milestones are used to show the data flow. Data flow management is the focus in this approach rather than to focus on the control flow. The positive consequence is that PDP is more transparent as the data sources of end-reports can be easily identified. International transparency is stabilised.

- Human resources are not distracted from production itself as the PDPM system can be fully automated. Due to the fact that human resources are expensive factors in PDP, the automation helps to effectively deploy them.

- The PDP system is not coupled to the PDPM system and can run fully independently and production delays are not risked due to the coupling method.

- Possibilities for a quick identification of production problems can be provided and key performance indicators are displayed on the fly. This contributes to effectively control PDP and to stabilise business success.

In section 6.3 the detailed concept of the PDPM prototype is introduced. How the PDPM system has been integrated in the available PDP system environment is explained. The schema of checkpoints, milestones and their dimensions is described. As this prototype is of interest for different user groups, the user groups have been categorized. Accordingly, user interfaces can be different for each user group. The user interfaces

which have been implemented during this research project are the following: The *Milestone-Administration* offers possibilities to cleverly filter milestones, predecessors and successors and their status information. Quick navigation through the huge milestone chain is possible. The *Rule-Administration* allows to create and update rules for planning the milestone due dates. A comfortable possibility to identify various problem cases is demonstrated with the user interface *Milestone-Statistics*. Different lists in form of rankings or other sequences show milestones which are for example delayed and not completed. The GUI *Milestone Progress* shows the adherence of due dates on examples of this PDP process and correspondingly informs management about the progress in production. Furthermore, it is outlined how this PDPM system can be fully automated to relieve production operators from creating and maintaining milestones. The used technology and the development process of the prototype is discussed in order to investigate pre-conditions and effort for possible future PDPM systems.

Section 6.4 shows that the concepts described in the loosely coupled approach are very robust. The answers to the questions what happens if checkpoints, connections, milestones or their dimensions are changed is that only in few cases the milestone history could get lost.

In section 6.5 a critical reflection of the prototype described in this chapter is provided. The problems identified, in relation to the PDPM prototype, during this research project, are outlined. Thus, problems in the following categories are described: functional problems, performance problems, amendment problems and scalability, prototype-related problems and social problems. Some problems led to further prototype iterations and have consequently improved the prototype through this procedure.

Chapter 7

Evaluation results of the prototype concept

Chapter objective

      The discussion of this research project has been advanced by evaluating the operational benefits that can be achieved. The evaluation is presented in this chapter and focuses rather on the concept of the loosely coupled approach than on the prototype. The reason is that a PDPM system is a very strategic-oriented tool and incorporates a lot of intangible benefits. A classic cost-benefit analysis of the prototype that measures tangible benefits may thus not reveal the true value of such a tool. The concept evaluation of the prototype is therefore of much more interest.

      The aim in this chapter is to introduce the approach used for evaluating the loosely coupled concept and to present the research results. This approach comprises the evaluation of financial and functional benefits on the operational, strategic and tactical level. Expert assessment questionnaires are analysed that present the experiences made with the prototype and the concept. Tangible and intangible benefits in relation to timing, costs, quality and future-orientation are evaluated by presenting different scenarios that can be supported with the concept. Due to the many intangibles the results are rather presented by weighting how good the benefits can be achieved than by presenting quantifiable values. The overall result is, the loosely coupled approach is useful in computerized supervision of periodic data production and demonstrates innovative but proven ways in managing the timing aspects in this application area.

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7 Evaluation results of the prototype concept

7.1 Introduction

This chapter provides a detailed evaluation of the loosely coupled approach for the IT support of PDPM that has been introduced in this thesis (see chapter 5). The evaluation results are presented as financial and functional benefits on operational, tactic and strategic management levels. Scenarios, which have been improved by using this concept, are presented to underline the outcomes. Experts which are main stakeholder of the prototype have been asked to answer specified questionnaires. The results of these expert assessment questionnaires are analysed.

In section 7.2 it is discussed that a PDPM system is a decision support system with the need for manually applying PDPM. This means that users should derive actions due to the information queried with such a system. The actions then re-affect the production status that can again be queried in the PDPM system. Without user actions, effects of production optimisation due to the availability of such a system will be missed.

Instead of only evaluating the implemented prototype, section 7.3 explains that the object of interest in this evaluation is the loosely coupled approach. One reason is that a concept is the fundamental base that often offers more functionalities than actually implemented in a prototype.

Section 7.4 looks at the evaluation criteria and structure used for evaluating the loosely coupled approach. Possibilities for evaluating information systems and their concepts are introduced and appropriate approaches are chosen. In this project an evaluation approach is used where scenarios are described and evaluated to provide a scenario-based assessment.

In section 7.5 the evaluation results of this research project are presented. Expert assessment questionnaires, are analysed and used to underline the research results. Financial and functional benefits are evaluated by presenting improved scenarios that can be achieved as a result of using the chosen approach.

Finally, a summary of the gained evaluation results is provided in section 7.6. The results of each scenario are summed up to an overall end-result.

7.2 Effects of applying periodic data production management on the evaluation

From the beginning of the discussion of PDPM it is indicated that a PDPM system

delivers decision support which is useful when applying PDPM. In this section, this interdependency between applied PDPM and a PDPM system is picked up again to discuss the economical reason of the effect that applying PDPM has on the evaluation of PDPM systems.
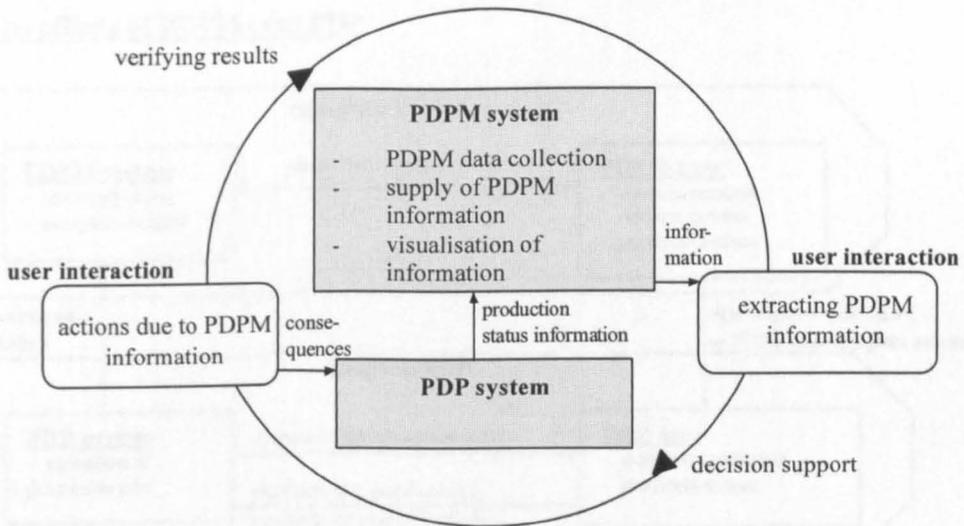
Figure 7.1: Impact-cycle of applied PDPM

The impact-cycle of a PDPM system and applied PDPM

The continuing business process of PDP leads to the insight that PDPM is also a continuing activity. Indeed, an impact-cycle can be identified when investigating this fact (see figure 7.1). This impact-cycle can be described as follows. A PDPM system delivers information about timing and status of PDP. User interaction is necessary to extract this information, but provides decision support for improving and managing PDP. At this point it is important that the user derives actions due to the gained information. Only if these actions are applied, their consequences can have an effect on the PDP system. For example, the information contains that a data package needs a shorter planned due date to meet the deadline of an end-report. The action of the user could be to shorten the planned due date of this data package. The necessary second action is that the responsible person produces this data package according to the newly planned due date. This has consequences for the PDP system as this affects the scheduling of events. After job execution, the PDP system informs the PDPM system about the new status. The user can now verify the results of his actions by querying again the PDPM information. Due to the new information the user is able to derive the next actions and so on. This impact-cycle demonstrates that a PDPM system cannot optimise production without actions applied by a user. PDPM is possible without a PDPM system, but a PDPM system without applying

PDPM is reduced to simply monitoring PDP. This is the reason why for each scenario in the following sections two situations are discussed:

- the situation applying PDPM information without using a PDPM system
- the situation using a PDPM system and applying PDPM information

The effects of PDPM onto PDP
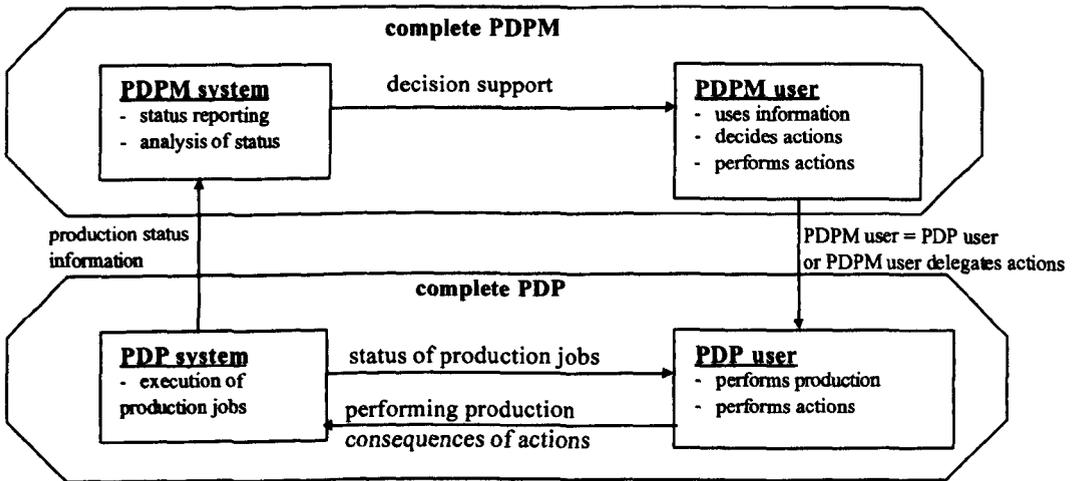
Figure 7.2: Interdependencies between PDPM and PDP

The nature of decision support systems is that the provided information influences user actions (Pierson & Cruz, 2005, 637). This effect can be demonstrated in the case of PDPM as well (see figure 7.2). When considering economical aspects, to have a PDPM system is not enough for applying PDPM. In fact, PDPM consists of a PDPM system that provides decision support and a PDPM user who employs the information, and decides, and performs actions. This is similar for PDP. PDP consists of a PDP user who triggers the PDP system to execute production jobs. The PDP system displays the status of the processed jobs to the PDP user. However, PDPM influences indirectly PDP. The PDPM user performs actions due to the PDPM information or delegates the actions to a PDP user. The PDP user applies the actions which influence in turn the PDP system. The PDPM system queries the production status and offers again decision support to its users.

Consequences of applying PDPM onto the evaluation of PDPM systems

The described impact-cycle has the following consequences in relation to the evaluation of a PDPM system:

- The quantity of the monetary benefits of a PDPM system depends on the intensity and quality of using the provided decision support. It is necessary that users apply actions (of high quality) due to the provided decision support.

- The more actions and the better the quality of the actions are, which have been derived from the provided decision support, the higher is the benefit and the return on investment of a PDPM system measured in a cost-benefit analysis. A PDPM system is accordingly a strategic-oriented tool.

- The evaluation of a return on investment in case of strategic-oriented management information systems is highly fluctuating and complex (Murphy & Simon, 2002, 301-320) and is therefore not used for the evaluation of this research project.

7.3   Object of evaluation

In this research project, two possible objects for an evaluation can be identified. These two objects are the loosely coupled approach and the implemented prototype that is based on this concept. In this section it is explained why the prototype only plays a minor role for evaluation in this research project. The main object to be evaluated is consequently the loosely coupled approach.

Information system evaluation in use

The implementation of the prototype has not been completed yet, because two out of eleven checkpoints have not been implemented due to internal incidents in the company. Optimising production due to the PDPM system is the request of the management board, but users still do not really use or take advantage of the decision support provided due to the lacking checkpoints. Instead, the prototype provides simple status monitoring at the moment, which is useful for creating a milestone history. The necessary impact-cycle of PDPM is in this case not implemented yet (see section 7.2). Although initial approaches exist for extending traditional cost-benefit analyses with the evaluation of intangible system benefits (Murphy & Simon, 2002, 301-320), the company decided to abstain from creating such an analysis. The reasons are the strategic-oriented character of this PDPM system, its many intangible benefits, the fact that this system is a prototype, and that the implementation is not completed yet. However, as only minor parts of the prototype are not implemented it still allows sufficient analysis and contributes valuable results to the evaluation (e.g. in form of expert assessment questionnaires (see appendix D)).

Concept evaluation

The evaluation of this research project is clearly independent from the implementation status of the prototype. For the purpose of this thesis it is of much more value to evaluate the concept that was implemented. Traditional cost-benefit analysis that

measures usually tangible benefits of systems may not reveal the true value of the concept. The efficiency of the loosely coupled approach is therefore the object of interest in this evaluation. The purpose of the prototype is to demonstrate that the concept is useful, that it can be implemented, and that it works as a robust fundament. Accordingly, the evaluation of the concept in this research project can be extended by the results derived from the experiences made with the prototype. The prototype especially demonstrates in which scenarios such a PDPM system is useful. Tangible and intangible benefits of the loosely coupled approach are weighted, discussed and evaluated by modelling scenarios that can be tested or can be created by employing the prototype. Such a scenario-based evaluation of the concept is usually an approach that is used during system design by involving users in the specification of functionality (Schaik, 1999, 455-466). In the case of this research project such a scenario-based evaluation is used after system implementation and supported by two reports of the prototype's experts, which are based on specified questionnaires.

7.4 Evaluation criteria and structure

Carefully chosen criteria and a clear structure are the pre-conditions for a profound evaluation. Arranging concise criteria and a structure of evaluation contributes to provable conclusions.

Research and possibilities for evaluating system design concepts are described in section 7.4.1. This section reflects which possibilities are available for evaluating the loosely coupled approach. The evaluation approach used and the structure for this evaluation are described in section 7.4.2. Finally, in section 7.4.3 it is depicted how the information for evaluating the concept has been gathered.

7.4.1 Evaluation possibilities

In literature, approaches for the evaluation of information systems are described. Other approaches that are more related to concept evaluation, concentrate on a scenario-based evaluation. All these approaches are discussed in relation to the evaluation of this research project.

Approaches for the evaluation of information systems

- *Cost-benefit analysis:*

Usually, managers are required to justify information systems financially by calculating a return on investment. Cost-benefit analyses are a standard method for such a

calculation. Farbey found out that managers often use easily estimable quantitative factors instead of calculating the true system's value by including qualitative and intangible benefits into this calculation (Farbey et al., 1992, 109-122). However, in the information systems area often important benefits exist which cannot be quantified easily. For example, improved workflow, interdepartmental co-ordination, increased customer satisfaction or the support of IT in substantiating decision making are intangible benefits (Emigh, 1999, 52-53; Katz, 1993, 33-39). All these examples are also key benefits of PDPM systems. The four main categories that can be identified in literature of intangible benefits are internal improvements or infrastructure investments, customer services, business foresights and adaptability issues (see figure 7.3).
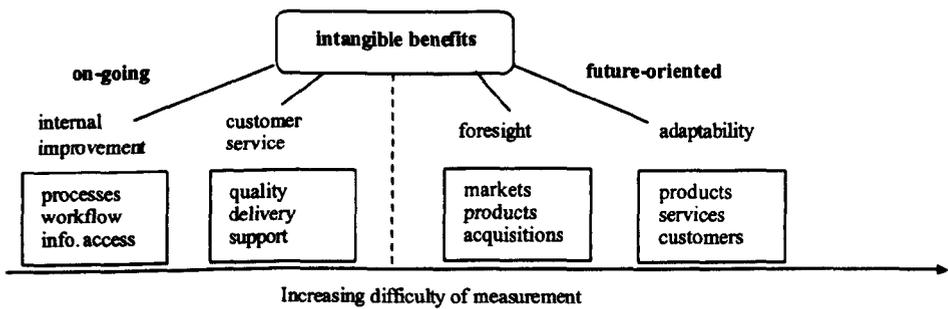
Figure 7.3: Intangible benefits (Murphy & Simon, 2002, 306; Hares & Royle, 1994)

Research shows that measuring intangible benefits is challenging. Irani and Love assumed with a case study of a MRPII investment that the more strategic-oriented the project is the more intangible and thus non-quantitative benefits play leading roles (see figure 7.4) (Irani & Love, 2001, 161-177). PDPM systems are no exceptions in relation to this assumption. As PDPM systems are strategic-oriented the number of intangible, non-quantitative benefits is higher than its tangible, quantitative benefits.
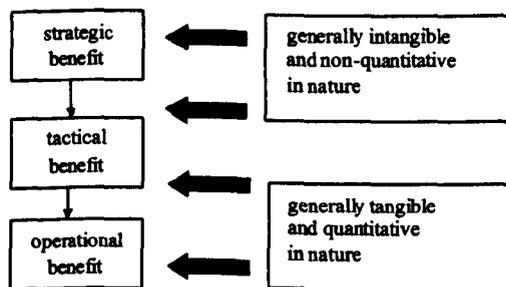
Figure 7.4: Nature of strategic, tactical and operational benefits (Irani & Love, 2001, 161-177)

Murphy and Simon argue that cost-benefit analysis falls short if intangible values cannot be quantified in monetary terms (Murphy & Simon, 2002, 306). However, they proposed an approach where some of the intangible benefits can be measured and calculated as monetary values. This approach advances traditional cost-benefit analyses

with intangible benefits. It measures for example the value of customer satisfaction that is measured by evaluating customer surveys. The result of their experiment is, the return on investment with included intangibles is higher than without.

In this research project, traditional cost-benefit analyses may not reveal the true value of the strategic-oriented PDPM system with its many intangible benefits. Interviews of customers or users in relation to the prototype were not available at the prototyping company, so intangibles could not be included into a cost-benefit analysis. Such an enriched cost-benefit analysis would also not show the effectiveness of the loosely coupled approach. Consequently, the calculation of a return on investment is not envisaged in this research project.

- *User interviews:*

Intangible benefits, as pointed out above, can be measured by using interview technology. User interviews evaluate for example such criteria as (Duden Informatik, 2001, 97):

- user-friendliness
- maintainability
- flexibility
- range of services offered
- security
- quality of results
- fairness
- performance

However, in case of the prototype the impact-cycle of PDPM and the PDPM system has not sufficiently been established due to the lack of the last two checkpoints. The number of active users was too small for guaranteeing anonymity in the evaluation. As the opinion of experts concerning the prototype is of much more interest than user interviews, therefore and in order to evaluate the prototype two involved main stakeholder of the company, which are experts of the implemented PDPM system, were asked to complete assessment questionnaires. The evaluation results of these reports can be found in section 7.5.1.

- *Performance measurements:*

Tests and software performance engineering are usually appropriate methods to evaluate information system benefits (Schmietendorf & Dumke, 2002, 67-75). Especially increases in performance are the targets of those approaches. However, in this research project, the focus lies not on the performance of the prototype. Such approaches do not contribute to an effective evaluation of the loosely coupled approach and are excluded

from further considerations.

<u>Approach for the evaluation of concepts</u>

- *Scenario-based evaluation:*

In literature, approaches for evaluating system models can be found. Approaches are especially involving users early in the stage of specification and functionality in system design. Damodaran argues that user involvement in system design has benefits such as improving the quality of a system, a possible avoidance of costly system features, a greater understanding of the system leads to improved acceptance, and an increased participation of users in decision-making (Damodaran, 1996, 363-377). One interesting and proven method in relation to this research project is to use scenarios for system design evaluation. Scenarios are a technique that supports early specification of functionality by involving potential users (Carroll & Rosson, 1992, 181-212). Schaik demonstrates the usefulness of the following possible strategy that can be used to achieve such an evaluation (see figure 7.5) (Schaik, 1999, 455-466):

initial specification $\longrightarrow$ scenario $\longrightarrow$ qualitative $\longrightarrow$ quantitative $\longrightarrow$ system
of functionality　design　evaluation　evaluation　requirements
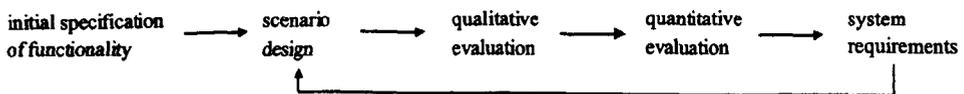
Figure 7.5: Strategy for specifying and evaluating functionality (Schaik, 1999, 455-466)

Schaiks approach proposes roughly the following major steps to evaluate system designs:

- defining scenarios that will be implemented after design
- interviewing users with questionnaires
- qualitative and quantitative analysis of results

This approach is generally used in this research project. However, as the loosely coupled approach is not in the design phase anymore, the concept has already been prototyped, and, as mentioned before, since user interviews are not possible, this approach needs to be further adjusted. The necessary adjustments are presented in the next section.

7.4.2　Evaluation approach in this project

As explained in section 7.4.1 conventional approaches, such as cost-benefit analyses, for evaluating information systems are not used for this evaluation. In principle, the evaluation approach from Schaik is used (Schaik, 1999, 455-466). This section presents how this is applied to evaluate the loosely coupled approach.

<u>Evaluation approach</u>

Schaik proposes in his method to use scenario descriptions in case of system design for the specification of functionality. He evaluates the importance of the functionality with

user interviews. In this research project the focus is not to find relevant requirements for system design, but to demonstrate the usefulness of a designed system concept by utilising scenarios. The quantitative analysis of user interviews is replaced by two significant expert assessment questionnaires of the prototype. The experts have been assessed as qualified to contribute the assessment questionnaires because they are the main stakeholder of the prototyped PDPM system which means their interest is high to achieve an effective system. This includes that critic is not omitted. They belong to the management board of the involved company and both have much experience with the assessment of concepts due to their software-oriented business. As action research is usually empirical, the evaluation results are supported by these expert assessment questionnaires. The following iterative process is used:

    I.   *Scenario:*
       - describing a scenario that is driven from the concept and improves time management
       - showing the usefulness of the scenarios with an example to demonstrate the achievable benefits
    II.   *Operational consequences:* describing the logical operational consequences
    III. *Chain of business effects:* showing the business effects that the scenario triggers
    IV. *Evaluation results:* weighting the expected effectiveness of improvements

Scenarios are described to show how time management can be improved by using the loosely coupled approach. Examples of the scenarios demonstrate their effectiveness and the achievable benefits. The benefits are examined by description of the logical operational consequences that are initiated by the scenarios. Considered are the following two situations: First, considered is the situation when applying PDPM without the support of a PDPM system. Second, the situation is considered when a PDPM system is available and the provided information is used. This implies that the impact-cycle of applying PDPM and PDPM system is properly installed.

The business effects that the scenario triggers are then discussed. The effectiveness of these improvements are weighted by interpreting the experts' assessment questionnaires, by using common knowledge about business processes, and by considering the logical consequences. The experts' assessment questionnaires especially show the opinions of the company which owns the prototype and consequently represent viewpoints which are important in industry. The assumption is that expert assessment questionnaires are usually more relevant and show higher interests than user interviews would represent. The results

are not derived as quantitative values from the two experts' questionnaires, since the number of these assessment questionnaires are not representative for a statistical analysis. Instead, the resulting benefits are weighted in relation to how effective or ineffective they can be achieved. This is useful because the intangible benefits can easily be integrated as well as the tangible benefits and as discussed in section 7.4.1 it is useful to include both types of benefits into an evaluation. By using this procedure the evaluation of the experts can be represented without a conversion into a cost-benefit analysis.

Structure and evaluation criteria in this research project

In this research project the criteria and the structure presented in table 7.1 is used for the evaluation of the loosely coupled approach. The chosen criteria is aligned to the catalogue of scenarios presented in section 7.5.

operational criteria	timing				costs			quality						future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
type of benefit	tangible, quanti-tative	intangible, non-quanti-tative	tangible, quanti-tative	tangible, quanti-tative	tangible, quanti-tative	tangible, quanti-tative	tangible, quanti-tative	tangible, quanti-tative	intangible, non-quanti-tative	intangible, non-quanti-tative	intangible, non-quanti-tative	intangible, non-quanti-tative	intangible, non-quanti-tative	intangible, non-quanti-tative

Table 7.1: Evaluation criteria and structure of concept evaluation

For each presented scenario the matrix of table 7.1 is filled to evaluate the operational benefits which can be achieved. Each benefit is weighted on the scale presented in table 7.2. The types of the benefits are provided in table 7.1 to present which of the benefits are usually intangible and which are tangible.

scale for intangible benefits		scale for monetary values	specification of benefits related to time	
++	highly achievable	high	com:	communication time reduction
+	achievable	moderate	cor:	coordination time reduction
blanc	not relevant in this scenario	low	w:	waiting time reduction
			d:	reduction of delays
			e:	quicker production error detection

Table 7.2: Evaluation scale table

The reasons for criteria selection in case of the PDPM systems' evaluation are summarised in table 7.3. (cp. table 7.1).

operational criteria	reason for criteria selection	benefit	type of benefit	reason for benefit selection
timing	optimisation in PDP can be achieved when time reductions can be identified. A main function of PDPM systems is therefore to enable the detection of idle times	reduction of times (delays, waiting times, error detection time, communication time and coordination time)	tangible, quantitative	avoiding delays, reduction of waiting times, less error detection time and shortening communication and coordination times are items that contribute to rationalisation goals
		improving production planning	intangible, non-quantitative	improvements of the process to plan production and plan improvements itself help to identify time reductions. Idle times can better be avoided
		decreasing peak loads	tangible, quantitative	the relocation of production loads to less production critical days helps to avoid idle times and delays
		increasing productivity	tangible, quantitative	a high productivity strengthens the business success of a company if the product quality does not decrease
costs	business success depends on profit. A PDPM system can contribute to lower production costs and to increase the profit of a company	penalty reduction	tangible, quantitative	if end-reports cannot be delivered in time penalties have to be paid to reimburse customers. To avoid penalties increases the profit.
		turnover increase	tangible, quantitative	an improved supervision process of PDP contributes to increase the turnover
		production cost reduction	tangible, quantitative	penalty reductions and optimising timing in production contribute to production cost reductions
quality	customer retention can be achieved by demonstrating a high-quality product. Such a product can be created by establishing a high-quality production process. A main goal of PDPM systems is to improve the process quality in PDP	improving product quality	tangible, quantitative	a high-quality product can conceive customers. PDPM systems improve process quality and contribute as a result to product quality improvement
		improving process quality	intangible, non-quantitative	business success depends on the result in PDP and on the process quality. PDPM systems are able to identify open potential for process improvements.
		enabling traceability	intangible, non-quantitative	PDPM systems visualise data flow dependencies. Past, current and future production can be queried. Peak loads can be identified and a smoother production process avoids waiting times and delays
		improving production overview	intangible, non-quantitative	key performance indicators aggregate business results. PDPM systems measure and visualise key performance indicators for PDP to deliver decision support

table to be continued on the next page

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operational criteria	reason for criteria selection	benefit	type of benefit	reason for benefit selection
		improving customer satisfaction	intangible, non-quantitative	if a company can demonstrate the high-quality of its products and the production process, customer satisfaction can be achieved and contributes to customer retention
future-orientation	the survival of a company in today's competitive markets depends on whether it is able to prepare for the future. A PDPM system is able to add a contribution	preventing quality reductions	intangible, non-quantitative	As PDPM systems offer computerised supervision of PDP, process quality reductions are measured and visualised and can therefore be prevented in future
		preparing against competitors	intangible, non-quantitative	competitors without computerised supervision of PDP usually have difficulties to demonstrate and to offer customers the same product and process quality than companies with PDPM systems

Table 7.3: Reasons for the selection of the evaluation criteria in case of PDPM system design concepts

7.4.3 Explanation of the information gathering process

The evaluation results of this research project are derived from several information sources. Which sources are used and how the information for the evaluation is gathered is explained in this section.

Information sources:

The evaluation results come from the following information sources:

- outcomes from the analyses of the expert assessment questionnaires
- logical operational consequences from the described scenarios
- general knowledge about business processes

Information gathering process:

The evaluation results are gathered by using the following methods:

- analysing the experts' assessment questionnaires for the evaluation of the prototype
- some scenarios are generated or reproduced to show benefits that can already be achieved by using the prototype
- other scenarios are in the nature of *'Gedankenexperimente'* (Brown, 2006) to show proposed benefits that are possible with the loosely coupled approach

For each scenario described in this evaluation it is therefore indicated if it was possible to query the information by using the prototype or if the information was created as *Gedankenexperiment*.

7.5 Evaluation

The results of the evaluation, which has been carried out to assess the loosely coupled approach, are presented in this section. This system design concept is evaluated by discussing its strengths and weaknesses with useful scenarios that can be achieved by applying this concept. For each scenario logical operational consequences are presented and the emerging tangible and intangible benefits are weighted. The results are substantiated with the analysis of expert assessment questionnaires for the implemented prototype. Model calculations give a clue and underline the profitability of PDPM systems, which are based on the loosely coupled concept, by using the example of the prototype.

In section 7.5.1 the results of the assessment questionnaires, which were written from the two experts of the prototype, are summarised. This is to provide a first overview of the evaluation results. As in this evaluation scenarios are presented that are useful in PDPM, an overview of the scenarios and their use is given in section 7.5.2. Afterwards, these scenarios are presented in detail. The scenarios themselves are divided into scenarios that are related to financial benefits (see section 7.5.3) and scenarios that demonstrate functional benefits (see section 7.5.4).

7.5.1 Overview of the analysis of the experts' assessment questionnaires

The prototype described in chapter 6 has been implemented in the market research company GfK Marketing Services. Two main stakeholder of this company which are experts of the implemented PDPM system have been asked to contribute to this evaluation by answering questionnaires in written form. Both original reports can be found in appendix D. In this section, the main results of the analysis of these expert reports are summarised. This section represents the interesting view of the industry to a PDPM system.

<u>Procedure of the questionnaire</u>

Both experts received a template of the questionnaire that they were asked to fill out. This template includes two parts. The first part contains nine questions (see table 7.4) that were asked to be answered in free written text. The aim was to ask each expert on his involvement in the prototype implementation, his opinion about the chosen concept and his evaluation of the prototype.

No.	questions	aim of questions	summarised in bullet point
Q1	the experts identification	expert position and focus in relation to the prototype	1A
Q2	the experts task in relation to prototype implementation	examples of tasks that the expert or his staff carry out related to the prototype	
Q3	definition and the need for data production management	expert view of why computer-aided data production management might be needed in industry	1B
Q4	requirements of a data production management system	expert view of the requirements for a cost-effective data production management system	
Q5	loosely coupled data production management (the design concept adopted for the prototype)	expert assessment of this design decision	1C
Q6	data production management with and without the prototype	expert assessment of the change resulting from the introduction of the prototype and of future needs	1D
Q7	effectiveness of the prototype	expert view whether the present and anticipated functions of the prototype gives them what they need and, if not, how they might be done better	1E
Q8	possible major enhancements in future	expert's ideas for major advances in scope in future	
Q9	overall evaluation	expert assessment of life with the prototype	1F

Table 7.4: Expert report questionnaire - part 1

In the second part a combination of numeric evaluations and free written text under two headings, is provided in a standard format. This was to find out what the experts assess as the most interesting PDPM issues in relation to the prototype. This ranking describes what key performance indicators they need and what they think that the strengths or weaknesses of the prototype are.

1. Summary of part 1:

In the following the results of the analysis of the assessment reports - part 1 are presented:

1A) *Expert identification, related tasks, and professional competence (related to Q1, Q2):*

Two division managers participated in this evaluation. Both are experts of the implemented PDPM system. One of those division managers is responsible for the correct and timely international and German market report production. His objectives for supporting the prototype were to gain a production overview where data dependencies are shown and production planning is advanced. One of the main tasks of this expert is to ensure a punctual and correct report production. Thus, time management supported by IT is crucial important for him and his production operators. Detailed overviews of delays in production are very important. To be able to adequately manage production, aggregated information of productivity, due date adherence, and Gantt reports are required.

The second division manager is the main initiator for implementing the prototype and responsible for system developments. His focus was to find a profound concept that can be developed to a reliable and robust base for time management in PDP and to supervise the implementation work. This expert is interested in the product management of the prototype. Performance, maintenance, possibilities for enhancements, scalability and reliability of the prototype's concept are important issues for this expert.

1B) *Definition and requirements of a PDPM system (related to Q3, Q4):*

Both of the experts define the cornerstones of a PDPM system as planning, monitoring and controlling a PDP system. This also reflects the name of the prototype: PCMS (i.e. Planning, Controlling and Monitoring System). The experts objective was to reduce the complexity of time management in PDP. Thus, the prototype had to focus on time management rather than cost or resource management. It is important for the expert to advance production planning in PDP and to reduce the complexity of deviation handling if data packages are replaced or deliveries are late. Summarised, the expert confirmed the following requirements of PDPM systems:

- showing the status of data packages throughout the workflow
- providing quality means to avoid production errors and to obtain an optimum of data packages scheduled within the allotted time
- overcoming data aggregations and separations
- coping with unstable data identifiers as data packages change their identification keys during production
- handling the frequent deviations at run-time
- using exception reporting for PDPM information reduction
- using the periodic repetition for automating the planning
- concentrating rather on progress monitoring than automating direct corrections in production

The experts opinions are largely conform to the description of the PDPM system's cornerstones provided in section 2.3.3. These opinions also summarize the general requirements of PDPM systems described in detail in section 2.3.1.

1C) *Assessment of the decision for the loosely coupled approach (related to Q5):*

Both experts preferred the loosely coupled approach in the case of computerized supervision of their PDP system. The main arguments were the following:

- advantageous is the independence between the PDPM system and the PDP system because a slow-down of production due to a coupling to a PDPM system cannot be accepted
- this concept supports a PDPM system that can easily be extended if production steps are changed

- this concept offers a tool that is standardized for the whole workflow and that provides international production overviews
- the opinion is that this concept can support high performance of the PDPM system so that it works next to real-time
- attractive is the support of legacy systems (i.e. an exiting Job Execution Environment)

1D) *PDPM with and without the prototype (related to Q6):*

The reports of both experts reflect the situation without the prototyped PDPM system. Only very rough and non-standardised production plans have been available on three stages in the workflow. Data dependencies could not be sufficiently queried. Timing and status of product pieces have mainly been estimated on 'feelings' and incidents. Key performance indicators have not been continuously available on a reliable base.

Although the prototype is still not in productive use due to the lack of the last two checkpoints, supervising the PDP system with the prototyped PDPM system is evaluated from both experts as possibility to overview production very detailed, standardized and reliable. Gantt diagrams and international overviews are now on the fly available. The possibility to query production cycles and to ensure production planning on the data-dependencies is provided. The replacement of estimating status and timing of product pieces through reliable measurements has been judged as absolutely necessary. The need for key performance indicators is recognized. However, the way of how to use the now gained PDPM information will still need further experiences and observations.

1E) *Effectiveness of the prototype and the company's future plans in relation to the prototype (related to Q7, Q8):*

The prototype has been evaluated as a profound first step to establish more sophisticated PDPM in this company. The concept of the prototype has convinced the experts that this type of PDPM system is suitable in practice. Both of them assess the visualisation that is provided by the prototype of the data-dependencies as adequate. Their goal to establish more transparency in production has thus been achieved. In their opinion the prototype has the potential to predict future bottlenecks before they actually happen. Production planning is now sufficiently supported by IT.

However, the performance of the prototype and the user-friendliness of the tools still need approval. The last two checkpoints need to be implemented and the performance has to be improved in the way that more than two countries can be supervised and the checking of milestone states can be done next to real-time. As a large amount of milestones need to be supervised, the experts still require stronger

condensed overviews, but these overviews of the milestones should not be on an aggregated level in order not to loose the details. Possibilities for drill-downs in future versions of the prototype might be an option. Another possibility is to advance exception reporting to cope with the wealth of milestones. Moreover, possibilities for what-if analyses have been requested for the assessment of production loads when customers ask for new panels. This means also to improve the forecast of future production.

1F) *The experts' overall evaluation (related to Q9):*

Advantages and disadvantages which the experts mentioned as the result of prototyping their PDPM system were the following:

Advantages:

- more overview of PDP than ever before
- solid PDPM system design and system concept well suited
- thousands of milestones can be managed
- the PDPM system can be easily extended
- the PDPM system is a future-proof investment

Disadvantages:

- the performance of the prototype still needs improvements
- the user-friendliness of the GUIs should be advanced

2. <u>Summary of part2</u>:

In the following the results of the analysis of the assessment reports - part 2 are presented. The ranking provided from both experts is averaged to show the general opinion:

2A) *Evaluation of today's implementation of the prototyped system:*

Both experts ranked the features of the prototyped system that were available prior to writing down this thesis. The three most positive and the three most negative ranked features are presented and are ordered by their importance. The rating scale is {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}:

Negative features:

- (ranking: -1 points): The user-friendliness of the web pages needs improvements
- (ranking: -0.5 points): The possibilities to identify problems needs to be advanced, as it is hard to query thousands of milestones and it is not possible to conclude from a delay of a milestone to a production error
- (ranking: 1 points): The uncompleted implementation status of the prototype

Positive features:

- (ranking: 3.5 points): The Gantt diagram called 'production intensity diagram' and the completeness of the key performance indicators

- (ranking: 3 points): The production planning possibilities and the reliability of the PDPM system

- (ranking: 2.5 points): The appropriateness of the provided key performance indicators, the transparency of past and current production, and the possibility to compare the current and the planned production

2B) *Long-term expectations of key performance indicators when the prototyped system is completed:*

The experts have ranked which key performance indicators or overviews are the most important features fir them in a completed version of their PDPM system. The three highest ranked issues are described in the following summary ordered by their importance. The rating scale is {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}:

- (ranking: 5 points): The experts most important feature is an adequate *production overview* of past, current and future production. Both experts indicate that the production overview in form of a milestone schedule is the right system design and easy to understand for all participants. As the current prototype version only shows the future production of the next ten days, it needs to be improved for a better prediction of production in future. However, to increase this time span can be easily achieved by increasing the performance of the prototype, since this is the only reason why the time span was limited.

- (ranking: 4.5 points): In the ranking the second important issues were *Gantt diagrams*. The proposed Gantt diagrams have been derived from the milestone database and are described and evaluated in section 7.5.4.2. These management overviews have been assessed as very valuable from both experts. The diagrams have previously been manually created on an ad hoc basis. The automated creation saves now a lot of manpower. When using the PDPM system the Gantt diagrams are available whenever requested on reliable milestone information and need not be manually created by production operators.

- (ranking: 4 points): Time management in form of *waiting time reduction*, *data delivery reliability*, and *product reliability* has been evaluated as important by the

experts. This is to support stability of PDP and to improve PDP through optimisation wherever and whenever possible.

7.5.2 Overview of the scenarios and their use

Prior to presenting evaluation results of the proposed scenarios, an overview is provided in this section where the scenarios are introduced and are positioned in the business context due to their use. This is to justify the selection of the scenarios and to show by whom the scenarios are used when carrying out PDPM.

Selection of scenarios

Only three of the most important scenarios are discussed in this chapter (see table 7.5) in order to show how the chosen evaluation approach works. As depicted in figure 7.6 the descriptions of the other scenarios are moved to appendix E.

summary of expert questionnaires	bullet points used for the analysis of the experts' assessment questionnaires in section 7.5.1								user types			
scenarios in section 7.5	1A	1B	1C	1D	1E	1F	2A	2B	production operator	production management	higher management	sales representative
7.5.3.1 correlating production costs and human resources to milestones										X	X	
7.5.4.1 expected due-dates if predecessors are delayed									X	X	X	
7.5.4.2 Gantt diagrams modified for PDPM	X			X			X	X	X	X	X	X

Table 7.5: The selection of scenarios derived from the experts' assessment questionnaires

The selection of the scenarios is well considered and mainly derived from the identified business needs in the experts' assessment questionnaires. This correlation is described in table 7.5 and table 7.6. In both tables the scenarios, which have been discussed for this evaluation, are presented in relation to their references in the experts' assessment questionnaires. Scenarios which have not been referenced in these reports are either not relevant for the company which owns the prototype (e.g. GfK Marketing Services has already solutions for accounting and was not interested in the achievable improvements presented in section 7.5.3.1), or the improvements which are achievable by using the scenarios have not been implemented in the former manual PDPM processes due to the fact that their preconditions where not fulfilled. Even though some scenarios might not be useful in the case study they can be of interest in future PDPM applications and are therefore discussed in this thesis. The latter reason implies that these scenarios especially improve PDPM by creating new control possibilities. Since these scenarios complement

PDPM they are added in this evaluation.

summary of expert questionnaires	bullet points used for the analysis of the experts' assessment questionnaires in section 7.5.1								user types			
scenarios in appendix E	1A	1B	1C	1D	1E	1F	2A	2B	production operator	production management	higher management	sales representative
E.1.1 the whole story: example of one production cycle	X	X		X			X	X	X	X		
E.1.2 work lists with priorities									X			
E.1.3 example for detecting problems in the production chain		X					X		X			
E.1.4 due-date planning and refinement	X	X		X			X		X	X		
E.1.5 reduction of waiting times								X		X		
E.1.6 detect origin of delays									X	X		
E.2.1 due-date adherence	X			X		X			X	X	X
E.2.2 throughput time statistics									X	X	X

Table 7.6: The selection of scenarios derived from the experts' assessment questionnaires shifted into appendix E

Scenario users

7.5.4.1 expected due dates
E.1.1 production cycle visualisation
E.1.2 work lists with priorities
E.1.3 problem detection
E.1.4 production planning

production status information

in time
- accurate reports
- capacity for new reports
expected due dates

7.5.3.1 accounting information and human resource capacity
7.5.4.1 expected due dates
7.5.4.2 Gantt diagrams
E.1.1 production cycle visualisation
E.1.4 production planning
E.1.5 reduction of waiting times
E.1.6 detect origin of delays
E.2.1 productivity
E.2.2 throughput time statistic

7.5.3.1 accounting information and human resource capacity
7.5.4.1 expected due dates
7.5.4.2 Gantt diagrams
E.1.6 detect origin of delays
E.2.1 productivity
E.2.2 throughput time statistic

7.5.4.1 expected due dates
7.5.4.2 Gantt diagrams
E.2.2 throughput time statistic

company intern

extern

reliability of service

Figure 7.6: Overview of PDPM scenarios and their users

In table 7.5 and in figure 7.6 an overview of the users of PDPM is provided in the economic context. For each user the scenarios that are carried out while performing PDPM are outlined. For each scenario the number of the section or appendix is shown, in which the scenario is described in detail. The scenarios can be divided into the categories financial and functional benefits and are described as follows:

Scenarios that relate to financial benefits (see section 7.5.3):

- section 7.5.3.1: Providing accounting information and measuring human resource capacities:
  section title: Correlating production costs and human resources to milestones.
  user: Production management and higher management can gain accounting information and human resource capacity measurements on the detailed milestone level.

Scenarios that relate to functional benefits (see section 7.5.4; appendix E):

Operational level:

- section 7.5.4.1: Expected due dates:
  section title: Expected due dates if predecessors are delayed.
  user: All of the four shown user groups are interested to know the milestones' expected due dates if predecessors are delayed. For example, sales representatives desire to adequately inform the customers.

- appendix E.1.1: Production cycle visualisation:
  section title: The whole story: example of one production cycle.
  user: Production operator and production management are interested in having a complete overview of production and data relationships.

- appendix E.1.2: Work lists with priorities:
  section title: Work lists with priorities.
  user: Production operators can use the work lists to easily divide important data packages from less important ones.

- appendix E.1.3: Problem detection:
  section title: Example for detecting problems in the production chain.
  user: production operators are able to identify delays in production. Delays can point to production problems.

- appendix E.1.4: Production planning:
  section title: Due-date planning and refinement.
  user: Production operator and production manager are able to plan and to refine due dates of milestones. Usually production managers want to find possibilities for time reductions, whereas operators want to plan their work.

- appendix E.1.5: Reduction of waiting times:
  section title: Reduction of waiting times.
  user: Production management wants to optimise production by reducing waiting times.

- appendix E.1.6: Detect origin of delays:
  section title: Detect origin of delays.
  user: Production management and higher management want to identify the

causes for delays. Reduction of delays can be achieved if the causes are prevented in future production cycles.

Strategic and tactical level:

- section 7.5.4.2: Gantt diagrams:
  section title: Gantt diagrams modified for periodic data production.
  user: Production management and higher management can identify the intensity of production over the time. Production critical days can be identified.

- appendix E.2.1: Productivity:
  section title: Due date adherence.
  user: Production management and higher management are interested to know the rate of delays in production. This is a useful key performance indicator for measuring the productivity in PDP.

- appendix E.2.2: Throughput time statistic:
  section title: Throughput time statistic.
  user: Production management and higher management will be able to estimate duration times of reports with such a report.

7.5.3   Financial benefits

In section 7.5.3.1 a scenario is described of how a complete accounting of PDP can be implemented as well as an overview of human resources can be achieved when using the loosely coupled approach. Its intangible benefits are the very detailed overview of costs and human resources on the milestone level and the precaution in relation to a preparation against competitors.

The profitability of the prototype is as explained not the focus in this thesis. However, model calculations are provided in section 7.5.3.2 that give an impression of how fast the development costs for a PDPM system are proposed to be amortised. This is shown on the example of the prototype.

7.5.3.1   Correlating production costs and human resources to milestones

The loosely coupled approach is based on the metaphor model traditional project management. Traditional project management typically does not only include time management. Usually, time, cost and resource management are considered together as their dependencies are of interest. The consequence for this research project is that cost and resource management need further attention. In this section, the scenario is described and evaluated of how costs and human resources can be correlated to milestones.

I.   Scenario

The idea: Costs and human resources can be measured and assigned to milestones (see figure 7.7). This would enable an effective accounting and work load balancing.

Considering details up to the level of the milestone's dimensions is possible. For example, in figure 7.7 at checkpoint CP1 the costs for each retailer can be distinguished, and at checkpoint CP2 the costs can be overviewed for each product-group. A summation of the costs gives clues about the total costs. Accounting overviews per milestone dimension, per country or international overviews are easily achievable.
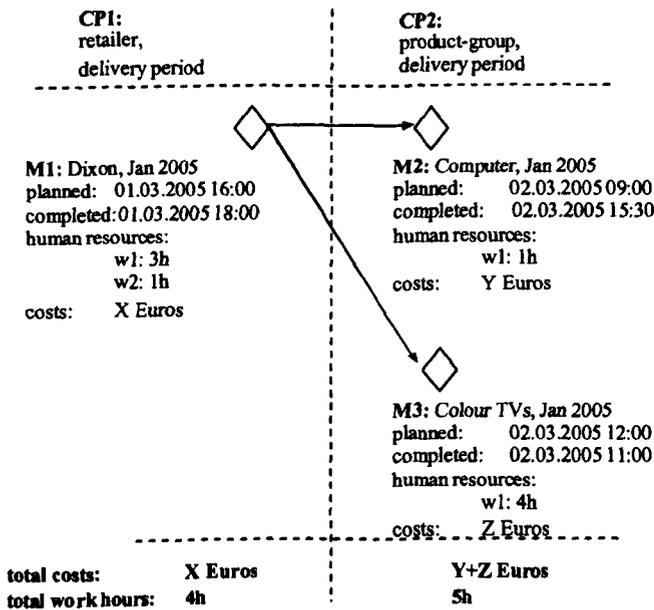
Figure 7.7: Scenario: Correlating costs and human resources to milestones

Measurement of costs: According to the product identifiers of a milestone (e.g. M2: product-group and reporting period) the costs need to be measured in production. This can be done in different ways: For example, each month the number of production jobs related to the milestone's product identifiers as well as the number of all production jobs of this month are queried in the PDP database. The quotient of both numbers expresses the share of production costs at the milestone. This can then be easily translated into monetary values as the fix costs of production are usually known.

Measurement of human resources: Although both would be possible, due to privacy issues it might be more advisable to measure only work hours instead of logging names of operators. A clever login service is needed for this measurement. Users need to login and specify the data packages that they work with. The time is logged and used for assigning work hours to milestones.

II. Operational consequences

The operational consequences of the described scenario are discussed in table 7.7. Considered are the situations in PDPM without the support of a PDPM system, and the situation when the impact-cycle of PDPM and PDP system is properly installed. This

scenario has not been implemented in GfK Marketing Services yet due to an existing alternative accounting system.

scenario: correlating costs and human resources to milestones	1.) situation without P DPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
preconditions	accounting by manually sharing production costs on an average base	costs and work hours are assigned to milestones on a time and effort basis	no	- fair accounting - knowledge of human resource capacities - identification of expensive end-report with low customer numbers - if additionally the processing time of servers will be measured then waiting times can be measured accurately.
derived actions	participating departments are charged on an average base; no measurement of work hours	participating departments are more accurately charged on real efforts		

Table 7.7: Operational consequences of correlating costs and human resources to milestones

The consequence of implementing this scenario in a PDPM system would be a fair accounting and resource management for all participating departments. Cost and resource overviews could be provided up to the level of detail that milestones are supporting. Due to the availability of the data flow dependencies in this concept, it is possible to identify expensive end-reports with low customer numbers. The sample of retailer data used for production can be improved by using this knowledge. If the processing times of production jobs and servers will additionally be correlated to milestones, an accurate measurement of waiting times can be enabled.

III. Chain of business effects
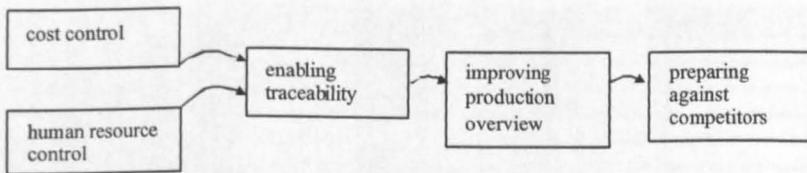
Figure 7.8: Economic effects of cost control and human resource control

Cost control and human resource control enable traceability in production (see figure 7.8). At each point in time it is clear how expensive a piece in production was. Cost and work load overviews improve the overview of production. The combination of these facts prepares a company against competitors, because the potential of PDP in relation to costs and human resources is better known by the management.

IV. Evaluation result

The basic control of costs and human resources does usually not lead to tremendous improvements or cost reductions (see table 7.8). However, the described scenario that can be implemented by using the loosely coupled concept is one piece in the puzzle of how to improve PDPM for controlling PDP. Slight improvements can be seen in the traceability of

PDP, more production overview is provided, and production costs can be controlled. This prepares the PDP company against its competitors.

operational criteria	timing				costs			quality				future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
correlating costs and human resources to milestones										+	+			+

Table 7.8: Evaluation results for the scenario: Correlating costs and human resources to milestones

7.5.3.2 Model calculations

The measurement of a real return on investment in case of strategic-oriented information systems is not possible without considering its intangible benefits. However, in this section, *model calculations* are provided that give an impression of a possible economic value of PDPM systems, which are based on the loosely coupled approach. Their profitability is investigated for values measured with the prototype that has been presented in this thesis and by using assumptions that will be explained in this section. The model calculations give clues about how long the amortisation period for the prototype can be estimated when replacing the manual investigation of delays in PDP with the tool-supported investigation of delays.

Prototype measurements:

month:	Jul 05	Aug 05	Sep 05	average
CP0	3355	3287	3256	
CP1	3322	3299	3231	
CP2	137119	104554	98923	
CP3	686	671	610	
CP4	690	690	611	
CP5	2474	2213	2153	
CP6	2315	2216	2130	
CP7	9331	8014	7610	
total	159292	124944	118524	134253

Table 7.9: Total number of milestones measured for three months with the prototype

The measurements presented in table 7.9 and table 7.10 have been extracted from the prototype's user interface Production-Progress (see section 6.3.4.4). The numbers and delays of milestones that have been monitored during a period of three month (July 2005-September 2005) are used as basis for the model calculations.

In table 7.9 the total numbers of milestones between checkpoint CP0 and CP7 are presented. Only those milestones which have a due date between the last day in the specified month minus 90 days (= roughly three months) and the last day in the month are counted. This is the reason why an average of the amount of milestones has been

calculated. The result is, or the average of the total number of milestones in three months is:

$n_{total\ (3\ months,\ 2\ countries)} = 134,253$ milestones.

This variable represents the number of milestones for two countries, which were observed with the prototype within 3 months. For one country and one month this can be reduced as follows:

$$n_{total\ (1\ month,\ 1\ country)} = n_{total\ (3months,\ 2\ countries)} / (2\ countries * 3\ month)$$
$$= 134,253\ milestones / 6 = 22,376\ milestones$$

Table 7.10 presents an overview of the amount of delays in percent during the period of the specified three months. The result is that in average 37% (= p_{delay}) of the milestones have been delayed in this period. This highlights that there is a great potential for improvements.

$p_{delay} = 0.37$: average of delays in percent

month:	Jul 05	Aug 05	Sep 05	average
avg. completed, delayed milestones in %:	31	26	24	
avg. not completed, delayed milestones in %:	11	10	8	
total in %:	42	36	32	37

Table 7.10: Milestone delays in percent measured for three months with the prototype

Assumptions:

In addition to the real values measured with the prototype, the model calculations are based on the following assumptions:

- A realistic assumption is that three percent of the delayed milestones will be checked by experts either with or without PDPM tool-support.

  $p_{check\ (3\%)} = 0.03$: delays in percent that will be checked

  A higher benefit can be expected when this rate would be increased. In this model calculation thirteen percent are assumed as alternative to show the consequences.

  $p_{check(13\%)} = 0.13$: delays in percent that will be checked

- The investigation time for the delay of one milestone by manually searching is

  $h_{manual} = 1h$

- The human resource costs for one man-hour are

  $c_{man-hour} = 60$ Euros/h

  The assumption is that the investigation of the reasons for delays needs experts and cannot sufficiently be solved from untrained staff.

- The development costs of the prototype can be estimated as follows:

  $c_{dev} = 250,000$ Euros

- A further assumption is that within a month new deviations cause delays and affect the rate of delays in percentage. The result is that a direct effect of the investigation procedure to a reduction of the delay rate might only be seen as a tendency.

<u>Formulas:</u>

A formula for the resulting benefit ($B_{auto\text{-}delay}$) needs to be created for determining the monetary value when using a PDPM tool and automating the delay investigations. For this reason the following variables have been prepared:

$n_{delay} = p_{delay} * n_{total}$ (1 month, 1 country)　　: number of milestones that are delayed

$n_{check} = p_{check} * n_{delay}$

$= p_{check} * p_{delay} * n_{total}$ (1 month, 1 country)　: number of milestones that will be checked from the experts

The costs for manually checking a milestone are the work-hours used multiplied with the costs for a man-hour:

c_{manual} (1 milestone) $= h_{manual} * c_{man\text{-}hour}$　　: costs for manually checking one milestone

$c_{automated}$ (1 milestone) $= f * c_{manual}$ (1 milestone)　: costs for automated checking one milestone; the size of the factor f determines the degree of automation ($f = 0$: fully automated checking; $0 < f < 1$: manual checking)

The monetary benefit per milestone that can be gained can be calculated by subtracting the costs for automated checking from the costs for manually checking:

$B_{(1\ milestone)} = c_{manual}$ (1 milestone) $- c_{automated}$ (1 milestone)　　/replacing $c_{automated}$ (1 milestone)

$= c_{manual}$ (1 milestone) $- f * c_{manual}$ (1 milestone)

$= (1 - f) * c_{manual}$ (1 milestone)

The resulting benefit for automating delay investigations can be defined as the benefit that can be gained per milestone multiplied with the number of milestones to be checked. This leads to the following formula for determining the resulting benefit $B_{auto\text{-}delay}$:

$B_{auto\text{-}delay}$ (1 month, 1 country) $(f) =$

$= B_{(1\ milestone)} * n_{check}$　　　　　　　　　　　　　/replacing n_{check}

$= B_{(1\ milestone)} * p_{check} * p_{delay} * n_{total}$ (1 month, 1 country)　/replacing $B_{(1\ milestone)}$

$= (1 - f) * c_{manual}$ (1 milestone) $* p_{check} * p_{delay} * n_{total}$ (1 month, 1 country)

/replacing c_{manual} (1 milestone)

$= (1 - f) * h_{manual} * c_{man\text{-}hour} * p_{check} * p_{delay} * n_{total}$ (1 month, 1 country)

In general, the resulting benefit $B_{auto\text{-}delay}$ for automating delay investigations can be defined as presented in figure 7.9. This formula can be used for roughly calculating the monetary benefit for automating delay investigations with any PDPM system and is not limited to the values calculated for the prototype.

$$B_{\text{auto-delay (x month, y countries)}}(f) = (1 - f) * h_{\text{manual}} * c_{\text{man-hour}} * p_{\text{check}} * p_{\text{delay}} * n_{\text{total (x month, y countries)}}$$

Figure 7.9: General formula for calculating the benefit for automating delay investigations with a PDPM system

Model calculations:

The general formula, created for the calculation of the benefit $B_{\text{auto-delay}}$, in relation to automating the delay investigations (see figure 7.9), is used in the following different scenarios to show the possible value of PDPM systems:

Scenario 1: One month and one country is investigated:

1. Case (f = 0): Experts manually investigate the milestones regarding delays. $B_{\text{auto-delay}}$ specifies in this case the costs for the manual investigation.

   $p_{\text{check (3%)}} = 0.03$: percent of the delayed milestones that are checked.

   $c_{\text{manual, total}} = \max(\ B_{\text{auto-delay (1 month, 1 country)}}(0)) =$

   $= (1 - 0) * 1h * 60\ \text{Euros/h} * 0.03 * 0.37 * 22{,}376$

   $= 14{,}902\ \text{Euros}$

   $p_{\text{check (13%)}} = 0.13$: percent of the delayed milestones that are checked.

   $c_{\text{manual, total}} = \max(\ B_{\text{auto-delay (1 month, 1 country)}}(0)) =$

   $= (1 - 0) * 1h * 60\ \text{Euros/h} * 0.13 * 0.37 * 22{,}376$

   $= 64{,}577\ \text{Euros}$

2. Case (f = ½): Experts investigate the milestones regarding delays by using a PDPM tool. The assumption is that they need half of the time for investigating the delayed milestones due to tool support and the costs can therefore be reduced to half. The savings in regard to the manual procedure are:

   $p_{\text{check (3%)}} = 0.03$: percent of the delayed milestones that are checked.

   $B_{\text{auto-delay (1 month, 1 country)}}(½) = (1 - ½) * 1h * 60\ \text{Euros/h} * 0.03 * 0.37 * 22{,}376$

   $= 7{,}451\ \text{Euros}$

   $p_{\text{check (13%)}} = 0.13$: percent of the delayed milestones that are checked.

   $B_{\text{auto-delay (1 month, 1 country)}}(½) = (1 - ½) * 1h * 60\ \text{Euros/h} * 0.13 * 0.37 * 22{,}376$

   $= 32{,}289\ \text{Euros}$

Scenario 2: One month and sixty countries are investigated. The assumption of sixty countries is chosen because the completed prototype will need to cover at least these quantities:

1. Case (f = 0): Experts manually investigate the milestones regarding delays. The costs for the manual investigation are:

   $p_{\text{check (3%)}} = 0.03$: percent of the delayed milestones that are checked.

$$c_{manual, total} = max(\ B_{auto\text{-}delay\ (1\ month,\ 60\ countries)}(0)) =$$

$$= B_{auto\text{-}delay\ (1\ month,\ 1\ country)}(0) * 60 = 14,902\ Euros * 60$$

$$= 894,120\ Euros$$

$p_{check(13\%)} = 0.13$: percent of the delayed milestones that are checked.

$$c_{manual, total} = max(\ B_{auto\text{-}delay\ (1\ month,\ 60\ countries)}(0)) =$$

$$= B_{auto\text{-}delay\ (1\ month,\ 1\ country)}(0) * 60 = 64,577\ Euros * 60$$

$$= 3,874,620\ Euros$$

2. Case ($f = \frac{1}{2}$): Experts investigate the milestones regarding delays by using a PDPM tool. The savings in regard to the manual procedure are:

$p_{check(3\%)} = 0.03$: percent of the delayed milestones that are checked.

$$B_{auto\text{-}delay\ (1\ month,\ 60\ countries)}(\tfrac{1}{2}) = B_{auto\text{-}delay\ (1\ month,\ 1\ country)}(\tfrac{1}{2}) * 60 =$$

$$= 7,451\ Euros * 60 = 447,060\ Euros$$

$p_{check(13\%)} = 0.13$: percent of the delayed milestones that are checked.

$$B_{auto\text{-}delay\ (1\ month,\ 60\ countries)}(\tfrac{1}{2}) = B_{auto\text{-}delay\ (1\ month,\ 1\ country)}(\tfrac{1}{2}) * 60 =$$

$$= 32,289\ Euros * 60 = 1,937,340\ Euros$$

The study of the scenarios leads to the result that the higher the number of investigated country branches is and the higher the total numbers of milestones are, the earlier is the PDPM system amortised and the earlier are the development costs returned. In the example used, the resulting benefit that can be gained in the case of investigating sixty countries exceeds the development costs for the PDPM system within a month if only investigating three percent of the delays:

$$B_{auto\text{-}delay\ (1\ month,\ 60\ countries)}(\tfrac{1}{2}) = 447,060\ Euros \qquad > c_{dev}$$

This means, using the prototype in practice after completing all checkpoints and after introducing sixty countries to the system can quickly lead to an amortisation of its development costs.

The investigation of delays usually implicates a possible saving in penalties if delays in future production periods can be avoided. The reduction of penalties would additionally represent a clear increase in profitability in these model calculations. However, the consideration of penalties was not included in the calculations due to respecting the privacy reasons of the GfK Marketing Services. Furthermore, the calculations do not consider the achievable intangible benefits as such values need to be first transformed into quantifiable values. Usually, intangible benefits contribute to increase the profitability.

7.5.4 Functional Benefits

The loosely coupled approach supports many functionalities for computerised supervision of PDP. In this section the functional benefits are demonstrated in form of scenarios that improve time management in PDP. The functional benefits are evaluated and the results are presented.

One selected scenarios that is related to the operational level in PDPM is shown in section 7.5.4.1. The scenario demonstrates how the prediction of expected due dates can be enabled when using the loosely coupled concept. Operational consequences are discussed and weighted as a result of this evaluation.

The scenarios which is selected representing achievements on the strategic and tactical level is shown in section 7.5.4.2. The scenario demonstrates how management gets reliable information about the status of PDP in relation to time management. Gantt diagrams that are modified for supporting sophisticated PDPM and their advantages and disadvantages are discussed. Again, the discussion of operational consequences and the weighted evaluation results are presented.

7.5.4.1 Operational level: Expected due dates if predecessors are delayed

The availability of the relationships between milestones enables the scenario presented in this section. The scenario describes how due dates are expected to change if predecessors of the investigated milestone are delayed. The former manual PDPM procedures in GfK Marketing Services did not include this analysis since the manual effort to find the data flow dependencies and to calculate the changes in due dates was to high for the complete production. The scenario demonstrates therefore new analysis possibilities and adds value to the management as the predictability of due dates increases.

I. Scenario

The purpose of this scenario is to get more transparency of the timing in advance when delays occur. Accordingly, this scenario increases the predictability concerning the completion of data package processing. If delays arise in previous workflow segments it would be of interest to know when the completion of processing data packages can be expected. Production operators and sales representatives could then plan in advance how delays affect their work or when customers need to be informed about delayed end-reports or how long it will take to fix the problems. The solution is to recalculate expected due dates by adding the time intervals, which lie between two adjacent milestones and are specified in the due date rules, in the case of delayed predecessors. In the example

presented in figure 7.10, milestone M4 and M5 are not completed but will be delayed because their relevant common predecessor M2 was delayed. As M2 is completed, predictions of the completion dates of M4 and M5 are possible. The calculation formula is simply to interpret the related rules between M2 and M4 by using the completion date instead of using the planned due date and to propose the outcome as expected due date for M4. For the calculation of the expected due date of M5 the rules between M4 and M5 are interpreted by using the expected due date of M4. The complete milestone chain of latter workflow segments can be informed accordingly.

CP2:   CP3:   CP4:

M1:
due: 02.Nov.2005 16:00
completed: 02.Nov.2005 18:25
complete: yes

M4:
due: 05.Nov.2005 16:00
completed: ---
complete: no
expected: 06.Nov.2005 16:00

M5:
due: 05.Nov.2005 18:00
completed: ---
complete: no
expected: 06.Nov.2005 18:00

M2:
due: 03.Nov.2005 16:00
completed: 04.Nov.2005 16:00
complete: yes

M3:
due: 02.Nov.2005 08:00
completed: 02.Nov.2005 07:25
complete: yes
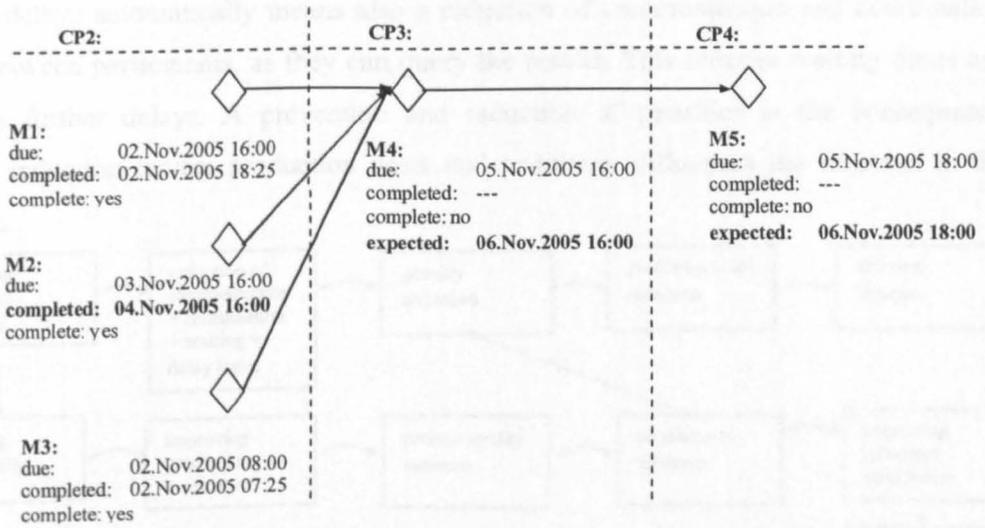
Figure 7.10: Example of calculating expected due dates if predecessors are delayed

II. Operational consequences

Enabling the calculation of expected due dates means that the prediction of consequences of delays can be improved (see table 7.11). This affects also the prediction of production critical days. Future peak loads can be more easily detected and dealt with accordingly. This flattens in the long-run the course of production.

scenario: calculating expected due dates if predecessors are delayed	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
derived actions	expected due dates in case of delayed predecessors are unknown	expected due dates are known and used to re-plan production accordingly	no	- consequences of delays can be planned in advance and their effects might be reduced - production critical days can be more accurately planned - smoother course of production can be achieved

Table 7.11: Operational consequences of calculating expected due dates if predecessors are delayed

III. Chain of business effects

The prediction of due dates in case of delayed predecessors leads to an

improvement in production planning as latter workflow participants are informed about impacts (see figure 7.11). This advances the production traceability and improves thus the production overview. The known impacts lead to an increase in process quality as future peak loads can be prevented. The increase in process quality leads respectively to an increase of the productivity because production operators are enabled to improve their plans. If the company can inform customers about delays in advance and if it has the production under control, customer satisfaction will be increased. This prepares the company in the long-run against competitors. Predicting and visualising the due dates in case of delays automatically means also a reduction of communication and coordination times between participants, as they can query the results. This reduces waiting times and prevents further delays. A prevention and reduction of penalties is the consequence. Penalty reduction lowers production costs and positively influences the turnover in the long-run.
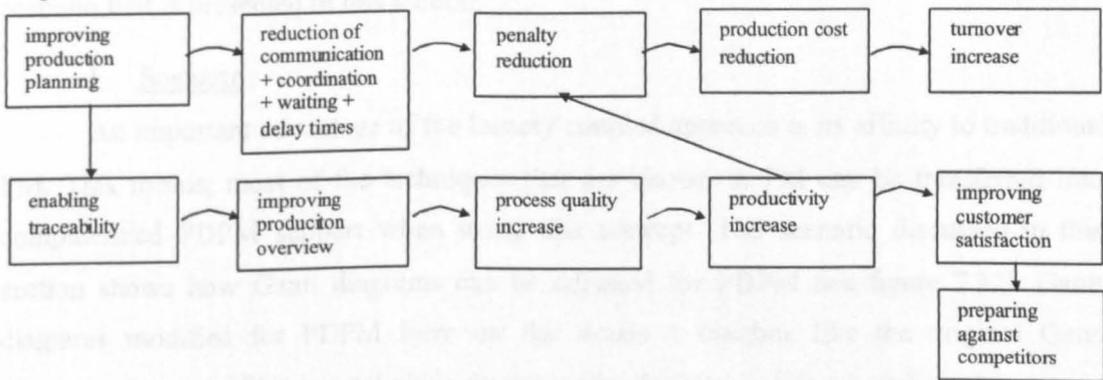
Figure 7.11: Economic effects of calculating expected due dates if predecessors are delayed

IV. Evaluation result

operational criteria	timing				costs			quality						future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
calculating expected due dates if predecessors are delayed	com,cor, w,d	++		++	high	low	low		++	++	++	++		+

communication time reduction	com
coordination time reduction	cor
waiting time reduction	w
reduction of delays	d
quicker production error detection	e

Table 7.12: Evaluation results for the scenario: Calculating expected due dates if predecessors are delayed

This scenario especially improves PDPM, as it assists the predictability of PDP (see table 7.12). Accordingly, its intangible benefits are evaluated as relevantly enhanced. It supports therefore very well the improvement of production planning, the increase of productivity and process quality. It enables traceability of PDP and improves the

production overview. Its tangible benefits are the excellent support for penalty reduction (e.g. in the case if it was possible to manually reduce the effects of delays) and the chance to save production costs and to increase the turnover. Altogether this intensifies the efforts to prepare the company against competitors.

7.5.4.2 Strategic and tactical level: Gantt diagrams modified for periodic data production management

Traditional Gantt charts provide graphical representations of scheduling plans for showing the project's activities and their progress. This is different in PDPM when using the loosely coupled approach because the activities are not monitored. However, the concept implies that milestones of PDP are monitored. They can be used to show Gantt charts that provide the production intensity, or delays and gains in timing regarding the monitored milestone dimensions. This useful fact is demonstrated and evaluated with the scenario that is presented in this section.

I. Scenario:

An important advantage of the loosely coupled approach is its affinity to traditional PM. This means, most of the techniques that are known in PM can be transferred into computerized PDPM support when using this concept. The scenario discussed in this section shows how Gantt diagrams can be adjusted for PDPM (see figure 7.12). Gantt diagrams modified for PDPM have on the x-axis a timeline like the original Gantt diagrams. Instead of having activities on the y-axis the idea in this research project was to replace activities by the dimensions that a milestone can have. For example, in figure 7.12 a Gantt report is presented that was created with the prototyped PDPM system and which shows on the y-axis the product-group 'Colour TVs'. The product-group is provided for specific checkpoint-areas (e.g. Data Entry = checkpoints CP0-CP2). In case of the prototype the following two different Gantt report types have been investigated:

Area	Start CP	End CP
Data Entry	0	2
Pre-processing	3	6
Delivery	7	7

Product Group	Area		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Data Entry	Planned			2	0	7	0	51	0	50	4	2	16	2	68	1	6	2
		Actual			5	15	17	0	2	0	0	51	5	16	24	12	0	3	0
CRT-TV (15520)	Pre-processing	Planned															1	0	0
		Actual																	2
	Delivery	Planned																	
		Actual																	

Figure 7.12: Extract of a production intensity diagram, a Gantt report in PDP

1. *Production intensity diagram:* The aim of this diagram is to inform staff about the peak times of data package processing. As this diagram shows the intensity of production per day, the diagram was named after this fact. The diagram contains for each day the calculated number of milestones which have their due dates (i.e. planned) or their completion dates (i.e. actual) in the shown timeline. In the example presented in figure 7.12, the planned peak times for producing the product-group 'Colour Tvs' for the checkpoints CP0-CP2 are at the 7th., 9th. and 14th. January 2005. At the 14th. January sixty-eight milestones are planned to be due. In reality, only twelve milestones have been completed at this day. The actual peak-load can be identified at the 10th. January where fifty-one milestones have been completed. All participants can now plan their work accordingly and identify easily the results of equalising bottlenecks by using this diagram.

   If a milestone dimension is not used in any of the shown areas (e.g. the dimension product-group is not used on the checkpoints CP0 and CP1), the predecessor and successor relationships between the milestones are used to accurately count the affected milestones.

Area	Start CP	End CP
Data Entry	0	2
Pre-processing	3	6
Delivery	7	7

Delivery Type	Area		1	2	3	4	5	6	7	8	9	10	11	12	13	14	Apr 2005 15	16	17
	Data Entry	Delayed	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Gained	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
METRO	Pre-processing	Delayed		1	2	3	4	5	6	7	8	9	10	11					
		Gained											10	10	10	10	10	10	10
	Delivery	Delayed																	
		Gained											12	12	12	11	11	11	11

Figure 7.13: Example of a delayed and gained diagram, a Gantt report in PDP

2. *Delay and gain diagram:* The aim of this diagram is to inform participants about the amount of days where milestones have been produced earlier than expected (i.e. gained) and about the amount of days of milestones that have been delayed each day. In the example shown in figure 7.13, the dimension 'delivery type' is used, which relates to the German retailer 'Metro'. For this retailer milestones have been delayed for two days in the data entry area (i.e. checkpoints CP0-CP2), and milestones have been gained representing forty-five days at the 1.Apr.2005. Similar to the production intensity diagram, the predecessor and successor relationships between milestones are used for calculating the number of days from milestones in checkpoint areas where the specified milestone dimensions are not available.

II. Operational consequences

The use of Gantt charts in PDP is important as summarised in table 7.13. Improvements in balancing the production loads on a international base between all participating distributed departments are achievable if the Gantt reports are available and reliable. Otherwise, the production would run on a first-in-first-out strategy. The risk would be that working groups block the productions of each other. To know the production intensity means that production can be coordinated and planned. A load balancing in PDP is then supported. The automated creation of the Gantt diagrams provides a reliable source of information, because the progress is directly measured in production. The planned and current production status can be compared easily.

scenario: using automated Gantt reports in PDP	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
pre-conditions	manual diagrams are only produced ad-hoc: costly diagrams	diagrams are automatically created: cheap diagram production	yes	- production intensity is known - delays and gains are known - production can be planned accordingly
IT support	diagrams are based on unreliable information	diagrams are produced on reliable milestone information; diagrams are ad-hoc created or in specified periods	GUI: Gantt report generation tool: not described in this thesis.	- load balancing of production is possible - based on a reliable information base
derived actions	only planned production is discussed; manpower is used for the creation of diagrams	diagrams are used to reduce peak-loads in production accordingly; planned and current production is compared to evaluate production progress; diagrams are used to re-plan production accordingly		

Table 7.13: Operational consequences of using automated Gantt reports in PDP

III. Chain of business effects
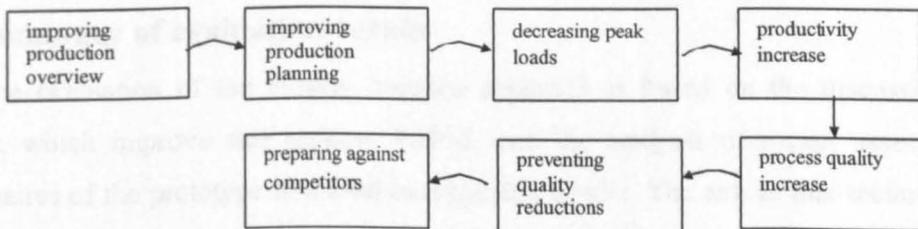
Figure 7.14: Economic effects of using automated Gantt reports in PDP

As shown in figure 7.14, Gantt reports improve the overview of production. As they contain information about production load situations, these charts help to coordinate and plan production loads for all distributed work groups. Peak loads can be reduced because re-coordination and re-planning production is possible due to the visualisation of the load situations. This affects the productivity as bottlenecks can be avoided. Avoiding

bottlenecks improves the process quality and helps therefore to prevent quality reductions in PDP. Improving the control of PDP prepares a company against its competitors.

IV. Evaluation result

The analysis of the expert assessment questionnaires shows the following two results. The first result is that the production intensity diagram is very useful and the automated support, which has been proposed in the prototype, is advantageous. However, the delay and gain diagram was assessed as not especially effective, because it is usually much more of interest which milestones are completed and what their priorities are. The report only informs about numbers of milestone per day and actually does not deliver this information.

operational criteria	timing				costs			quality					future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
using automated Gantt reports in PDP		++	++	++					++		+		++	++

Table 7.14: Evaluation results for the scenario: Using automated Gantt reports in PDP

The overall evaluation of the investigation of Gantt charts in relation to PDP is that the production intensity report contributes immensely to improve production planning and to decrease peak loads (see table 7.14). It is a tool for coordinating PDP on an international base and contributes to a productivity increase. Process quality is improved for all participants and quality reductions are avoided. This small improvement of the production overview leads in the long-run to a good production control which helps a company to be prepared against competitors.

7.6 Summary of evaluation results

The evaluation of the loosely coupled approach is based on the discussion of scenarios, which improve and support PDPM, and the analysis of expert assessment questionnaires of the prototype to underline objective results. The aim in this section is to summarise and weight the evaluation results discovered for the scenarios presented in section 7.5 and appendix E at prototype stage. The achievable benefits are ranked to provide an overall result. This demonstrates what the proposed concept for computerized supervision of PDPM is capable to contribute to the management of PDP.

operational criteria / benefits	section	timing				costs			quality					future-orientation	
		reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
correlating costs and human resources to milestones	7.5.3.1										+	+			+
calculating expected due dates if predecessors are delayed	7.5.4.1	com,cor,w,d	++		++	high	low	low		++	++	++	++		+
using Gantt reports	7.5.4.2		++	++	++					++		+		++	++
displaying the production cycles of reports	E.1.1		+						+	++	++			+	+
work lists with priorities	E.1.2	com, d	++	+						++		+			
detecting problems in the production chain	E.1.3	com,w,d,e			+	high	low	low		++		+	+	++	+
due date planning and refinement	E.1.4	com,w	++		++	high	moderate	low		++		+			++
detecting and reducing waiting times	E.1.5	com,cor,w	+		+	high	low	low		+					+
detecting the origin of delays	E.1.6		+			low				++		+		++	
measuring the due date adherence	E.2.1		++	+	++					++		+		++	++
using throughput time statistics	E.2.2		+	+						++		+		++	
sum		com, cor, w, d, e	14	5	10	high	moderate	low	—	18	5	11	4	11	11
results (18-10: high, 9-0: low)		---	high	low	high	---	---	---	---	high	low	high	low	high	high

Table 7.15: Summary of evaluation results

Firstly, the model calculations presented in chapter 7.5.3.2 have demonstrated that tool support for PDPM amortises after a relatively short time period. Savings in penalty payments and the inclusion of intangible benefits can increase this financial benefit. However, the achievable profit depends highly on the quality of applied PDPM and the chosen actions due to the visualised PDPM information. Considering this fact and because a PDPM system is a strong strategic-oriented tool the return on investment that can be achieved is estimated as moderate (see table 7.15).

Secondly, the evaluation of the presented scenarios can be summarised to an overall end-result as demonstrated in table 7.15. Each row represents the evaluation results of a scenario. Each column represents an achievable benefit. The results of each benefit are added to a sum as follows:

++ (highly achievable):   corresponds to 2 points
+ (achievable):   corresponds to 1 point

The points of each column are added to an overall sum for the considered benefit. The results are classified into two clusters (i.e. cluster 'high': 18-10 points and cluster 'low': 9-0 points). Thus, a rough ranking is achieved. The summarisation results of the scenarios' evaluation regarding time management in PDP are to be interpreted for the cluster which includes the results ranked as 'high' as follows:

1. (ranking: 18 points): PDPM systems that are based on this concept are able to improve vitally the quality of the PDP process.

2. (ranking: 14 points): Production planning is significantly enhanced when using the loosely coupled approach.

3. (ranking: 11 points): As the concept is able to improve the production overview intangible benefits that strengthen the future-orientation, such as preventing quality reductions and supporting the preparation against competitors, can be effectively advanced.

Another summarisation and illustration of the overall results is the discussion and enumeration of the main disadvantages and advantages as follows:

Disadvantages:
- (the concept lacks an automation of control. This lack arises because it was a functional requirement (see section 2.3.1). However, future research in this area could focus on advancing the original concept with automating functions for controlling.)
- production problems cannot directly be identified due to the lack of this information in the PDPM system. However, delayed milestones point to production problems and contribute to identify production errors early.
- as milestones usually imply several production jobs their waiting times can only indirectly be detected. However, waiting time reductions are possible by comparing the completion dates of milestones in former periods.
- throughput time measurements have usually to be averaged and are therefore based on imprecise calculations. The reason is that several milestones and/or several related production jobs need to be aggregated to accomplish these measurements.

Neutral aspects:
- a moderate return on investment is achievable as a PDPM system is most of all a strategic-oriented tool for improving the quality of the PDP processes.
- only decision support is delivered and manual actions need to follow. This is the nature of decision support systems.

Advantages:
+ the process quality can be vitally improved. The improved transparency of the workflow offers profound decision support for users through reliable measurements of PDP.

+ enhanced production planning is possible as it is in traditional productions. The usually *cost-intensive manual planning effort is reduced to a minimum* by using 'due date rules'.

+ advanced overview of data flow dependencies have been achieved. The milestone's predecessor and successor relationships support traceability of the end-reports' history of origins.

+ peak loads can be decreased. The course of production can be influenced and high fluctuations can appropriately be avoided.

+ a reduction of penalties is achievable. As delays can more effectively be detected and circumvented by using this PDPM tool-support, penalty payments to customers caused by such delays can be avoided.

+ customer satisfaction and retention are intensified. A high process quality, the process transparency, and punctual product deliveries contribute to convince customers about the quality of a PDP company.

The loosely coupled approach is consequently a relevant candidate concept for introducing a PDPM system in PDP which has more effectiveness than weaknesses. Although the experienced performance problems, with the prototype is demonstrated that decision support on an international base is possible and that the information is helpful for a quick identification of the right actions to retain and increase the productivity in PDP. Companies which employ a PDP achieve profound and standardised management information by applying this concept.

7.7 Chapter summary

This chapter discusses the evaluation of the loosely coupled approach. This approach is evaluated because the prototype presented in this thesis is based on this concept. In contrast to the possibility of prototype evaluation, the evaluation of the approach is emphasised. Improved scenarios are described to show the advantages and disadvantages when using this concept. The outcomes are underlined by expert assessment questionnaires that have been contributed from main stakeholders of the prototype. Tests with the scenarios which were implemented in the prototype have contributed experiences. The evaluation results are presented in this chapter.

In section 7.2 the effect of applying PDPM onto the evaluation is discussed. As the pure availability of a PDPM system does not optimise PDP, it is explained in this section that users need to derive actions from the information gathered with the PDPM system. If these actions are well chosen, the results of optimising PDP affects the information visualised with the PDPM system. If not the right actions or no actions are derived, then the PDPM system is a simple monitoring system. The better the derived actions are, the more optimisation in PDP can be reached and the bigger is the return on investment of a

PDPM system. The evaluation of the loosely coupled approach should hence not only focus on the measurement of a return on investment since this can fluctuate.

Section 7.3 defines the object of evaluation that is evaluated in this thesis. Due to the effects of applying PDPM and the incomplete status of the prototype, there is still lack of users who work with the prototype and too few actions for measuring the optimisation degree in PDP were derived. These facts led to the insight that prototype evaluation might not show the real value of the loosely coupled approach. Furthermore, a PDPM system based on this concept has a lot of intangible and thus non-quantifiable benefits, which will not be considered in a traditional cost-benefit analysis. Therefore, an evaluation approach has been chosen which enables a scenario-based evaluation of the loosely coupled approach. This approach implies the description of scenarios and the discussion of its business effects. The outcome is supported by the analysis of the assessment questionnaires which have been answered from prototype experts.

The evaluation criteria and the structure used for evaluation are described in section 7.4. The available evaluation possibilities of information systems and concepts are outlined. Information systems can be evaluated by a cost-benefit analysis, user interviews, or performance measurements. Concept evaluation can be done by the description of scenarios, by conducting user interviews, and by its quantitative and qualitative analysis. The chosen approach in this research project is the concept evaluation adjusted in this case as user interviews are replaced by more meaningful expert assessment questionnaires. As more intangible benefits are available in case of the strategic-oriented PDPM systems, the quantitative and qualitative analysis is replaced by weighting the achievable benefits that have been derived from the analysis of the expert assessment questionnaires. The information on this evaluation are consequently derived from the expert assessment questionnaires and from the logical operational consequences that are occurring while using PDPM systems.

In section 7.5 a detailed analysis of the expert assessment questionnaires is provided. The result is that the experts are convinced that a PDPM system, which is based on the loosely coupled approach, is useful for managing PDP. In their opinion the approach is robust, has the potential to improve typical PDP scenarios and contributes to prepare the company for the future. Furthermore, the possible variety of scenarios is discussed in this section. Scenarios that show financial benefits give the opportunity to extend the milestones towards a robust accounting system and model calculations which show that a PDPM system amortises relatively quick in comparison to manual procedures. Scenarios

which show and evaluate functional benefits are divided into scenarios on the operational level and on the strategic and tactical level. On the operational level it is demonstrated that the approach can be used to show in advance expected due dates if the predecessors of milestones are delayed. On the strategic and tactical level, aggregated management information can be provided. A scenario is presented and evaluated that shows that especially Gantt diagrams can be modified for PDP. These diagrams have been strongly recommended from the experts of the prototype and their strength is demonstrated. Finally, the evaluation results of all discussed scenarios are summarised and ranked for presenting the total outcomes. The result is that the loosely coupled approach is able to cover all significant possibilities of PM in PDP. A PDPM system that is based on this concept provides mainly improvements in relation to the quality of the PDP process, enhances significantly production planning and empowers the production overview in the way that quality reductions can be prevented and a company is able to support its preparation against competitors.

Chapter 8

Discussion: System design for periodic data production management

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Chapter objective

> *The aim in this chapter is to discuss all issues that are presented in this research. Results and possibilities in relation to the proposed concepts and the implemented prototype are reflected to complete the portrayal of sophisticated periodic data production management in this research project. The research issues that have arisen at the beginning of this project are reconsidered. Main findings are highlighted. The contribution that this thesis supplies to the research community is reviewed. Finally, perspectives and useful future work in this research area are introduced.*

Chapter contents

8.1 Introduction

8.2 Main findings discussed in the context of the research issues

8.3 Contribution of the thesis

8.4 Future work

8.5 Concluding remarks

8 Discussion: System design for periodic data production management

8.1 Introduction

At the beginning of this research project there was a business problem of the market research company GfK Marketing Services. This company required to improve its manual supervision process for *periodic data production* (PDP). On the first sight, to find solutions in form of commercial representatives for IT-aided supervision seemed to be trivial, as scheduling problems are known and research in this area is still in progress. However, on the second sight, this real-world business problem has led to new and interesting research for the previously unknown *periodic data production management* (PDPM) systems. To study such systems was useful as PDP especially combines concepts of data processing and traditional production. IT-aided management was not established in the PDP area and the management systems used for traditional goods production, or used for data processing systems, were not suitable enough to solve the management problems of this relevant combination. The analysis in this research project shows that PDPM systems have own requirements which are not addressed in currently available management systems from other areas. Both proposed system design concepts are able to solve these shortcomings and are especially effective in adding IT-support for the management of PDP environments. This chapter highlights the outcomes of this research project.

In section 8.2 main findings are summarised by discussing the chosen research issues. Section 8.3 emphasises the contribution of this thesis to the research community in this area. Possible enhancements of this research project and future work in this field are discussed in section 8.4. Concluding remarks are outlined in section 8.5.

8.2 Main findings discussed in the context of the research issues

The research issues which are selected in section 1.3.3 are finally answered in this section. Main findings are extracted and show that the following aspects can be derived from this research project:

<u>Main findings for issue1:</u>   What are the requirements for PDPM and what properties are critically important for a successful PDPM?

1. Identification and definition of a new type of information system: the PDPM system
   (cp. section 2.2.4)

Similar to the experience in goods production that the need in manufacturing is to have adequate IT-aided management, the idea in this thesis was to investigate whether PDP systems, which support periodic data production processes, can have analogous IT-aided management systems. The aims, to control timing, costs and resources, coincide in goods management systems as well as in PDPM systems. As the latter system type has neither been described in previous research nor in literature, a detailed analysis of its characteristics is necessary. The many differences between goods production systems and PDP systems have to be reflected in PDPM system design concepts and are investigated in this thesis.

2. The characteristics of PDPM systems (cp. section 2.3):

This research shows that PDPM is multifunctional (cp. section 1.2.2). An underlying PDP system is a mixture of a traditional production system and a data processing system. Accordingly, a PDPM system needs to consider the nature of this mixture (cp. section 3.2.1). The investigations lead to the result that the most important properties of PDPM are the automated support of planning, monitoring and controlling PDP processes (cp. section 2.3.3).

The following functional requirements of PDPM have been identified prior to the design of the system concepts proposed in this research project. They are motivated and explained in more detail in section 2.3.1. These requirements are not limited to the prototype environment and can be used for system design in this application area in general:

- Showing production status information
- Ensuring process quality
- Overcoming problems with aggregations, separations, and unstable product identifiers
- Handling the frequent deviations at run-time
- Support of exception reporting
- Take advantage of repeating production in intervals
- Monitoring instead of directly controlling production

<u>Main findings for issue2:</u>   What possible system design alternatives are there for satisfying the identified critical PDPM properties and are the various strategies particularly relevant for specific scenarios?

1. Possible system design concepts (cp. section 5.2):

The approaches where project management systems are combined with workflow management systems which have been identified in literature (cp. section 3.3) might only be useful in very static PDP environments (e.g. no deviations, no changing product identifiers, non-repetitive, etc.). Consequently, several system design concepts for the application area of PDPM systems have been proposed and investigated in this research project (cp. section 5.2; appendix A). The generic problem of how to introduce a management system on top of an unchangeable production system needed to be resolved (cp. section 5.3). The following two main candidate approaches have been proposed:

- Closely coupled approach (cp. section 5.2.2):

  This approach offers detailed semi-automated planning on the job level. The PDPM system plans each production job by using scheduling algorithms and engaging manual user support as often re-planning might be necessary due to the many usual deviations in PDP. These plans and job release-messages are communicated to the PDP system. The PDP system executes the production jobs and sends ready-messages back to the PDPM system. Due to this bi-directional communication between both systems this system design concept includes a close coupling between a PDP and a PDPM system to enable the 'release-ready mechanism'.

- Loosely coupled approach (cp. section 5.2.3):

  Almost fully automated production planning on a virtual aggregated milestone level is proposed in this approach. Milestones represent the data packages to be tracked. The milestones have relationships to show the dependencies between predecessor and successor data packages and their timing. Automated planning is achieved by taking advantage out of the repetition of production in intervals. The PDP system and its PDPM system are only loosely coupled. This means that no communication between both systems is necessary. Instead, only the production status is queried from the PDPM system by using the PDP system's database. Although, the PDPM system periodically queries this production progress, the

advantage is both systems can run practically independent from each other.

2. *Comparison of relevant candidate approaches* (cp. section 5.2.4):

To add value to the discussion, both candidate approaches were compared. This provides knowledge to the research community and decision support for system designers. The comparison has delivered the following summarised results:

- Closely coupled approach:

    This approach is mainly relevant if a main business goal of an interested organisation is to achieve a high optimisation degree of its PDP system. This high degree is achievable as a result of the detailed planning functions. Using this approach can be recommended and is more likely for small to medium-sized PDP systems, with a relatively small number of data packages and few deviations. The reason is, the company needs to deploy an adequate number of human planners which support the planning and re-planning in this approach. It is appropriate for PDP environments with strongly restricted resources due to its detailed planning approach.

- Loosely coupled approach:

    This approach is more likely to be relevant for large-sized PDP systems, where a high number of data packages and many deviations are expected. It is useful and can be recommended in PDP environments where optional data deliveries are allowed. The independence between the PDP and the PDPM system is a main advantage of this approach as interested organisations do not risk any slow-downs in their PDP system. This approach is applicable if the resources in the PDP systems are moderately restricted due to the fact that job processing is only advanced by assigning priorities to jobs.

3. *Effectiveness of approach for specific scenarios* (cp. section 7.5):

Although the implementation of improved scenarios can differ in the proposed approaches, it usually makes sense to investigate the same scenarios which can improve PDPM, for all the approaches. Due to the large size of PDP factories, in this research project one prototype was possible so far, and has enabled the scenario discussion for the loosely coupled approach. Prototyping of other approaches in the future can add a contribution to this discussion. Summarised, the both approaches and the scenarios in which they are effective can be described as follows:

- Closely coupled approach:

  Specific scenarios of this approach have not been further investigated. However, this approach is not less relevant in practice. The only reasons why this approach has not been chosen for prototyping were to meet the size and preferences of the involved company.

- Loosely coupled approach:

  The investigation shows specific scenarios in which this approach is effective are the following (cp. section 7.5; appendix E):

  - (cp. section 7.5.3.1) Production costs and human resources can be assigned to milestones to improve the overview of cost-intensive productions.
  - (cp. section 7.5.4.1) Showing expected due dates if predecessors are delayed for improving the future production plan.
  - (cp. section 7.5.4.2) Providing Gantt diagrams for deriving the production intensity and avoiding production critical days.
  - (cp. appendix E.1.1) Visualising production cycles and data flow dependencies for improving the transparency of the PDP processes.
  - (cp. appendix E.1.2) Work lists with priorities can be provided to support users by identifying important data packages.
  - (cp. appendix E.1.3) Early detection of problems in the production chain to avoid delays.
  - (cp. appendix E.1.4) Semi-automated due date planning and refinement to optimise production.
  - (cp. appendix E.1.5) Reduction of waiting times.
  - (cp. appendix E.1.6) Detecting and analysing the origins of delays to avoid similar situations in future periods.
  - (cp. appendix E.2.1) Showing the production progress for giving the management clues which workflow parts need to be improved.
  - (cp. appendix E.2.2) Providing throughput time statistics for identifying long duration times.

Main findings for issue3:   How can new system design concepts for PDPM best be evaluated, in practical terms, and what are the most effective criteria for evaluation?

1. *Possible evaluation approach and evaluation criteria*

  PDPM systems are management information systems and belong to the class of decision support systems. A popular approach for evaluating the value and effectiveness of information systems is a cost-benefit analysis. However, especially in the case of strategic-oriented decision support systems such as PDPM systems, it is still an open research question how their intangible benefits (e.g. decision support, customer satisfaction, etc.) can be adequately quantified and captured in a return on investment as it is proposed in traditional cost-benefit analyses (Murphy & Simon, 2002, 301-302). In case of PDPM systems the return depends on how frequently the decision support is

used and on the quality of the actions that are derived due to the decision support. The same monetary fluctuations are expected when using user interviews or performance measurements as evaluation approaches. The insight was that all these classic approaches may not reveal the true value of the investigated system design concept. Although cost-benefit analyses, user interviews and performance measurements are commonly used approaches, the research in this project has shown that it is preferable to use evaluation approaches that focus rather on the system concept than on the profitability of its prototypes.

In literature, scenario-based evaluations are identifiable as appropriate methods to evaluate system concepts for management information systems such as PDPM systems (cp. 7.4.1). Basis of the evaluation in this research project is an approach proposed from Schaik (Schaik, 1999, 455-466). Schaik suggests to establish a scenario-based evaluation prior to system design by describing scenarios and its quantitative and qualitative evaluation by applying user interviews. This approach can be adjusted for the evaluation of PDPM system design concepts after the design phase. For the designed system concept, scenarios are described which are achievable by using the concept. The expert assessment questionnaires, as provided in this research project, or user interviews are possible for gaining insights and results. As discussed in section 7.4.2 effective criteria for evaluation are the benefits that are the operational consequences of the discussed scenarios. As explained it is necessary to consider quantifiable tangible and non-quantifiable intangible benefits when discussing strategic-oriented information systems. Such criteria and the reasons for their selection in case of the PDPM systems are provided in section 7.4.2, table 7.3, and are summarised in the following:

- *Operational criteria:* timing
  Benefits:
  - reduction of times (delays, waiting times, error detection time, communication and coordination time)
  - improving production planning
  - decreasing peak loads
  - increasing productivity
- *Operational criteria: costs*
  Benefits:
  - penalty reduction
  - turnover increase
  - production cost reduction

— *Operational criteria: quality*
Benefits:

- improving process quality
- enabling traceability
- improving production overview
- improving customer satisfaction

— *Operational criteria: future-orientation*
Benefits:

- preventing quality reductions
- preparing against competitors

The evaluation results can be weighted depending on the expert assessment questionnaires or the user interviews to find strength and weak points of the investigated system design concept.

2. *Results of concept evaluation (cp. section 7.5):*

The loosely coupled approach has been evaluated. Positive and negative effects have been gathered. The outcomes can be summarised as follows:

- (cp. section 7.5.3.2) Main results of the model calculation:

A general formula (cp. figure 7.9) has been set up that can be used for roughly calculating the monetary benefit of a PDPM system when replacing the manual investigation of delays in PDP with the tool-supported investigation of delays. It has been used to estimate the length of the amortisation period for the prototype. The result is that if only three percent of the delays are investigated by using tool-support within sixty involved country-branches, the estimated development costs of the prototype can then be returned within a month. This demonstrates that tool support for PDPM amortises after a relatively short period in time.

- (cp. section 7.6) Main results of the scenario-based evaluation:

Disadvantages:

- (the concept lacks an automation of control. This lack arises because it was a functional requirement (cp. section 2.3.1). However, future research in this area could focus on advancing the original concept with automating functions for controlling.)
- production problems cannot directly be identified due to the lack of this information in the PDPM system. However, delayed milestones point to production problems and contribute to identify production errors early.
- as milestones usually imply several production jobs their waiting times can only indirectly be detected. However, waiting time reductions are possible by comparing the completion dates of milestones in former periods.
- throughput time measurements have usually to be averaged and are therefore based on imprecise calculations. The reason is that several milestones and/or

several related production jobs need to be aggregated to accomplish these measurements.

Neutral aspects:
- a moderate return on investment is achievable as a PDPM system is most of all a strategic-oriented tool for improving the quality of the PDP processes.
- only decision support is delivered and manual actions need to follow. This is the nature of decision support systems.

Advantages:
+ the process quality can be vitally improved. The improved transparency of the workflow offers profound decision support for users through reliable measurements of PDP.
+ enhanced production planning is possible as it is in traditional productions. The usually cost-intensive manual planning effort is reduced to a minimum by using 'due date rules'.
+ advanced overview of data flow dependencies have been achieved. The milestone's predecessor and successor relationships support traceability of the end-reports' history of origins.
+ peak loads can be decreased. The course of production can be influenced and high fluctuations can appropriately be avoided.
+ a reduction of penalties is achievable. As delays can more effectively be detected and circumvented by using this PDPM tool-support, penalty payments to customers caused by such delays can be avoided.
+ customer satisfaction and retention are intensified. A high process quality, the process transparency, and punctual product deliveries contribute to convince customers about the quality of a PDP company.

The study of the advantages reveals that the investigated system design concept meets to a high degree the discovered requirements (cp. section 2.3.1). In addition, the evaluation results demonstrate, that rather more important issues can be identified as advantages than as disadvantages. The conclusion is that the loosely coupled approach is a relevant concept for introducing a PDPM system in PDP and its advantages prevail. These results are underlined by considering the expert assessment questionnaires and the prototype results in industry. In addition, the prototype demonstrates that an implementation by using web technologies perfectly fits into the distributed PDP environment and that a PDPM system based upon the loosely coupled approach can effectively be used to cope with the problems that distributed environments incorporate.

<u>Main findings for issue 4:</u>   To what extent is prototyping all or part of proposed new system design concepts and tools a viable approach to testing and evaluation?

1. Prototyping is suitable for testing system concepts

The experiences made during this research project show that prototyping is a very useful approach for testing a new system concept. The prototype which has been implemented in industry, has crucially contributed to identify dead ends and appropriate features (cp. section 6.3; cp. section 6.5). The iterative development methodology was a validating factor for refining the automated supervision in the huge PDP environment. A continuous enlargement of the supported PDPM functionalities was possible. This leads to the insight that prototyping is a viable approach for testing and for finding optional concepts.

2. Results of prototyping the loosely coupled approach (cp. section 6.3):

The following summarised experiences were discovered during prototyping the loosely coupled approach in a real-world PDP environment:

- (cp. section 6.3.1) How and where in the workflow the introduction of checkpoints is useful. The loosely coupled approach uses checkpoints in the PDP workflow as templates for milestone instances. The setting of checkpoints should therefore thoroughly be thought through and be agreed by all participants. Respectively, checkpoints should simply represent the most important points and/or the interfaces between different departments in the workflow in order to reduce management information.

- (cp. section 6.3.2) Which milestone dimensions and attributes do make sense to overcome aggregations and separations between milestone neighbours. Choosing milestone dimensions depends on what the observed data packages mainly contain. Usually the primary keys are useful dimensions. However, as milestones are representing a more abstract virtual level, not every primary key needs to be used. This selection can reduce the amount of milestones and contributes to meet performance goals.

- (cp. section 6.3.2) How to query the data flow between checkpoints to be able to store milestone relationships. It should be taken into account that the data flow and the status information between checkpoints need to be available in correlated database tables to enable the availability of milestone relationships.

- (cp. section 6.3.2) Which status information is relevant to show adequate production progress. In case of the prototype we proposed several status information for milestones such as 'active', 'complete' and 'checked'. Other PDPM systems might need different or added status information. The status information itself and their interpretation needs to be defined individually in each application case to meet company requirements.

- (cp. section 6.3.3) Which user groups are interested. The managerial user group requires aggregated information, whereas production operators require detailed information. This implies that a drill down of information is necessary.

- (cp. section 6.3.4) Which information requirements can be satisfied in relation to time management in PDP. In case of the prototype several GUIs have been implemented to satisfy the information requirements and can be seen as proposal for other PDPM system implementations. These GUIs enable users to administrate milestones (cp. section 6.3.4.1), to administrate rules for the due dates of milestones (cp. section 6.3.4.2), to easily identify production problems (cp. section 6.3.4.3) and to query the adherence of due dates as a significant key performance indicator for PDP (cp. section 6.3.4.4).

- (cp. section 6.3.5) How to automate the milestone creation. Background procedures have been established and show how a PDPM system can be implemented.

- (cp. section 6.4) How robust the concept's adaptation capability is. As milestones and their connections are automatically adjusted whenever necessary in the dynamic PDP environment the loosely coupled approach can be seen as a very robust concept. Only if the workflow or the production steps are changed, checkpoints, their connections or milestone dimensions might be needed to be rearranged. Consequently, it can become necessary to change the PDPM background procedures and there is a risk to loose parts of the milestone history. Due to the fact that this is only triggered from major changes to the PDP system itself, this seems to be acceptable.

3. *The scenario-based approach should be preferred for system concept evaluation.*

It cannot be recommended to base the whole evaluation of a PDPM system's design concept on an implemented prototype. The reason why is the dependency of applying PDPM and its effect to the PDPM system (cp. section 7.2). As a PDPM system is a decision support system its success is dependent on the ability of users to derive the

right actions due to this decision support. This ability determines the return on investment and can therefore highly fluctuate between different implementations (cp. section 7.3). Cost-benefit analyses which are traditionally used to evaluate information systems would consequently not deliver the real value of a prototype. The same conclusion can be drawn for evaluation techniques such as user interviews or performance measurements. The true value of a PDPM system design concept may not be revealed. Consequently, a scenario-based evaluation technique as described in section 7.4.1 should be preferred (cp. section 7.4.2).

8.3   Contribution of the thesis

The research area of PDPM systems is complex as different traditional research fields have to be combined. Nevertheless, a result of the literature review was that concepts for PDPM systems have not yet been available regardless whether academic or commercial ones. As a consequence this new type of decision support system is analysed and described in this thesis in order to contribute knowledge about PDPM systems to the research community (cp. section 2.3). After the identification of important PDPM systems characteristics, several approaches in form of system design concepts are developed and discussed (cp. section 5.2; appendix A). Two main approaches promise to deliver sophisticated PDPM systems: the so-called *closely coupled approach* and the *loosely coupled approach*. They are based on well-known metaphor applications to benefit from available established research results about other management concepts. However, each of the proposed candidate approach has advantages and disadvantages. As a single system design concept can never cover the diversity of PDP systems in industry, the candidate approaches are compared to provide a better understanding of their benefits and restrictions (cp. section 5.2.4). This provides decision support for system designers which are interested in finding appropriate concepts for PDPM systems.

For gaining more detailed insight, a prototype based on the loosely coupled approach has been launched into practice (cp. chapter 6). It has been implemented as a real-world application at a leading market research company (cp. appendix B). The detailed activities of planning, developing, programming and implementing the concept were accordingly effective for evaluating this research project. On the basis of experiences in practice this prototype shows the possibilities and benefits of a PDPM system based on this approach. Concept details and possible user interfaces are described (cp. section 6.3).

In addition to the comparison of both candidate approaches, a detailed evaluation for showing the effectiveness of the loosely coupled approach is provided (cp. chapter 7). Only this approach is evaluated as the implemented prototype is based upon it. Model calculations are presented in this thesis that give clues about the monetary benefit of the prototype. However, the concept evaluation of the loosely coupled approach has been emphasized in this project instead of evaluating the prototype (cp. section 7.4.1). Since finding adequate evaluation approaches is difficult in case of such strategic-oriented decision support systems with many intangible and therefore non-quantifiable benefits, it is demonstrated how new scenario-based evaluation techniques can be used to show the benefits of PDPM systems. This means, a useful evaluation approach is to discuss the advantages of the concepts by means of improved scenarios and to discuss their operational consequences. Scenario selection can for example be taken from expert assessment questionnaires by identifying the crucial business needs. If the benefits that can be gained in these scenarios are weighted and proven with the expert assessment questionnaires, then an overall evaluation result can be presented which shows the relevance of the benefits that the system design concept can support (cp. section 7.4.2). The outcome in this research project is that PDPM systems are able to contribute to quality improvements of the underlying PDP processes, to enhance production planning, to reduce penalty payments as less end-reports are delayed and to help in the long-run to intensify customer satisfaction and retention (cp. section 7.6).

8.4 Future work

The presented research results offer further potential for additional investigations. Some of the main opportunities and challenges that this work provides are discussed in this section, on the basis of issues which could not be investigated in depth.

1. *Studying user issues:*

   Researching issues which are relevant for user will contribute to meet the needs of users concerning this business in more detail. This will help to improve the user-friendliness of PDPM applications which was not focused in this research project.

2. *Investigation of alternative system design concepts:*

   During this research project only the loosely coupled approach has been prototyped and evaluated in detail. A prototype and an evaluation of the closely coupled approach would contribute further experience in this application area. This includes the

definition and investigation of useful scenarios in this case. The evaluation results of the scenarios could then be compared to the evaluation results of the scenarios that have been defined for the loosely coupled approach. Strength, weaknesses and recommendations of the approaches could additionally be substantiated.

Due to the high diversity in industry it might be of interest to find further alternative system design concepts and to discuss their efficiencies. Such system concepts can be necessary when investigating different PDP areas, as for example, the periodical production of meteorological weather data. The investigation of this research project was fairly restricted to the market research environment and the research of different areas might lead to supplementary results. This includes that an investigation of management information systems for other data production types is attractive. For example, the differences between data production without the limitation to periodic data production and PDP are of interest.

3. Continuing research into specifics of the loosely coupled approach

One of the main idea in this research was to introduce content-aware milestones, checkpoints and their connections. This basis could be used in order to continue investigations of graph theories. For example, the research of a critical path method and the calculation of path lengths in PDPM is of high interest and leads to extending production overviews by using further possibilities of project management.

Moreover, research into a 'plug-and-play' mechanism for checkpoint insertion, connection modifications, and dimension adjustment might improve the approach.

Another idea is to investigate new variants of the approach. For example, the variant to drop the fix checkpoint levels in order to condense unimportant and to give prominence to important milestones is of interest for new research.

4. Investigation of other application areas:

The proposed system design concepts focus on the computerized supervision, and in particular on computerized time management, of PDP processes. However, it is advantageous to investigate the proposed approaches for their effectiveness in other application areas. For example, the following areas are of interest:

- Parcel tracking services:

  In package-oriented data production environments it might be of interest to research for time management in data package tracking services, where customers can track their ordered products.

- Supply chain management:

    It might be useful to enhance PDPM systems and especially the milestone concept of the loosely coupled approach for introducing time management in supply chain management. The major advantage of a global time management would be the improved coordination between all cooperating distributed business partners.

5. *Standardising PDPM systems:*

    - Standardising PDPM products or incorporating PDPM in other systems

        Prior to this research project, neither academic nor commercial PDPM systems have been available on the market. This is the reason why it might be advantageous to research towards PDPM systems as standardised software products. Possible are complete package solutions or modules that can be used to complement available legacy systems (e.g. modules for time management, resource management or cost management). Due to the similarity of WFM, research in relation to an incorporation of PDPM techniques into WFM systems is interesting. Cross pollinations should be investigated. This research should advance different variants in relation to the coupling mechanisms. WFM systems should be enhanced in relation to planning PDP, either with closely coupled and loosely coupled approaches.

    - Investigating PDPM systems as new software product lines:

        McGregor describes product lines as a software development approach which incorporates a software reuse scheme for fast and cost-effective generation of applications within a specific domain (McGregor, 2004, 65-67). The system design concepts which the applications of a product line use are very similar, and where possible software components are shared. In addition, each application can have application-specific features. Examples where this promising development approach has been adapted demonstrate that a high level of reuse can be obtained within all phases of development. The results are shorter development times, reduced costs and applications with lower defect rates. Hewlett-Packard, for example, was able to reduce the defect rate of software applications about twenty-five percent by using a product line development approach (Toft, Coleman, Ohta, 2000). Another example is Cummins Inc. which is one of the worlds leading manufacturers of large diesel engines. This company has demonstrated that the effort for the development of

a software for a new engine was effectively reduced from 250 man-month to three man-month by using product lines (Dager, 2000).
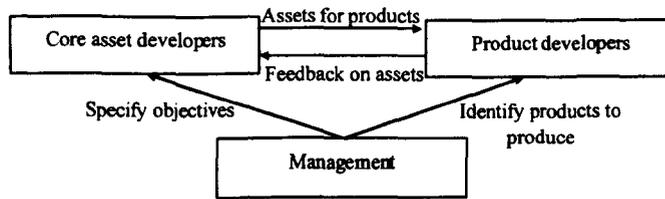
Figure 8.1: Roles of software product line (McGregor, 2004, 66)

According to the definition used by the Software Engineering Institute (SEI), a software product line is a set of software-intensive systems sharing a common, managed set of features that satisfy needs of a particular market or mission, and that are developed from a common set of core assets (i.e. a resource that is used to produce multiple products) in a prescribed way (Clements, 2001). The main roles in product line organisations are core asset developers, product developers and product line managers (see figure 8.1). The core asset developers create assets in form of architectures, specifications and implementations. Product developers use the assets for producing specific products that are derived from the assets. Product line manager coordinate this work and specify the objectives for generating assets and identify the products to be produced. Strategic goals are to choose products by minimising variants and maximising the reuse of components. This leads to the development of a product line architecture which entails sufficient capacity for modifications to include all of the products in the product line. The product line architecture is a kind of template for the products which are instances of the template and include usually application-specific features.

In the application area of PDP it is especially beneficial to investigate the use of product lines for the software development of different instances of PDPM systems. Basic product line architectures could be similar system design concepts to the proposed closely and loosely coupled system approach in this thesis. Derived from these product line architectures the various differences in industry of PDP can be investigated and specified in different product instances. Product lines of PDPM systems can enormously contribute to fast implementation of cost-effective applications in this area. Research for PDPM system's product lines offers therefore great potential.

8.5   Concluding remarks

Due to today's highly competitive markets, PDP systems and their computerized supervision with PDPM systems will become more and more important to process increasing amounts of data in shorter periods. It can be expected that market research, government administration, company internal research, and geo- and meteorological environments enlarge their efforts for performing PDPs. The result is that computerized supervision techniques can become crucial for guaranteeing business success. This is the reason why further research in this extraordinary application area is valuable and future-oriented. Advancing the possibilities of time, resource and cost management that PDPM systems provide will effectively contribute to keep control of the steadily increasing PDP systems.

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Glossary

aggregation	"The process of consolidating data values into a single value. For example, sales data could be collected on a daily basis and then be aggregated to the week level, the week data could be aggregated to the month level, and so on. The data can then be referred to as aggregate data. *Aggregation* is synonymous with summarization, and aggregate data is synonymous with summary data." (Oracle Corporation, 2006, p. Glossary-1)
changing product identifiers	Input data packages are processed and transformed into output data packages at each production step in PDP. Consequently, data packages are not stable elements. The primary keys of a data package can change after processing a production step. This change in primary keys is referred to as the *changing product identifiers* of data packages. For example, a data package has the delivery period 'calendar week 1 2006'. After this source data package has been processed at a production step, a new destination data package has been produced. This new data package has the reporting period 'Jan. 2006'.
checkpoint	*Checkpoints* are used to represent points of interest in a PDP workflow. Indeed, a checkpoint is a classical milestone. For avoiding confusions between classic and context-aware milestones, the term checkpoint is used instead of classical milestone. Checkpoints are templates for context-aware milestones and are used for production control. A context-aware milestone belongs exactly to one checkpoint and inherits its common properties (i.e. dimensions).
connection type	The *type of a connection* to a predecessor or successor milestone can be either, an 'initial' connection as this connection was planned, or a 'latest' connection as this connection is actually produced and valid. Consequently, it is usual to have one initial and one latest connection to the same predecessor / successor milestone. To store the connection type is crucial to be able to calculate the difference between planned and actual production.
data order	*Data orders* are derived from the definitions of reports. Each specifies the data content, which is needed to satisfy one or more report's calculation base. A data order has a due date to which the specified data is required to be ready for reporting in order to be able to finish the related reports in time. A data order is forwarded from the reporting backwards to the data entrance in order to inform production operators.

data package	A data package is a bundle of data stored in a file or a database table. In PDP data from sources are bundled into data packages which flow in a defined order from one production step to the next. For example, sources in the market research industry can be retailers which deliver in specified intervals their sales values. Each retailer delivers its sales values in a data package in defined intervals.
deviations, dynamic time scheduling	In PDP deviations can arise out of dynamic time scheduling, if data sources deliver late or if delays in production appear unexpectedly.
deviations, dynamic changes of input data	It is a mathematical principle that while gathering the input data for a statistical report, single values of the sample are not important. The same statistical report can be produced by using different sample data. This is the reason why data packages in PDP can be replaced with only minor effects on the resulting statistical reports. Usually, a data package which is used to replace another has a similar size and data content than the replaced one. If such a replacement appears this is a *deviation* for PDP which *arises out of these dynamic changes of input data*. These deviations often emerge during run time and cannot be foreseen reliably. As they occur usually unexpected, expert knowledge is required to handle them. An example for this type of deviation is that the data packages can be substituted if they fall below a defined quality standard.
dimensions of a context-aware milestone	Context-aware milestones are identified with the primary keys of data packages which flow through the workflow. Accordingly, these primary keys are the dimensions of a milestone. The milestone dimensions applied in the market research company used as example in this thesis are the following: - delivery type: primary key of retailer - delivery period period in which the retailer has sold the products - productgroup: grouping of products from the same type (e.g. 'colour TV's') - reporting period: period which is used in an end-report - project: specifies specific data pools For example, a context-aware milestone has the two dimensions delivery type and delivery period. In this case it could have a delivery type which refers to the retailer 'Dixons' and a delivery period which might be 'March 2005' when it is instantiated during run-time.
due date	Each milestone has a due date, which defines when the milestone is expected to be complete.

entry package	An entry package informs the PDPM system about the arrival of a data package at the distributed PDP system's entrances. An entry package is specified through dimensions such as for example a retailer and a delivery period. The entry package is sent as a message to the centralised PDPM system. The background procedures of this system identify the corresponding milestones and set them to the status 'complete'.
fact	This term is used in data warehouses. "Data, usually numeric and additive, that can be examined and analyzed. Examples include sales, cost, and profit. *Fact* and measure are synonymous; fact is more commonly used with relational environments, measure is more commonly used with multidimensional environments." A fact table is "a table in a star schema that contains facts. A fact table typically has two types of columns: those that contain facts and those that are foreign keys to dimension tables. The primary key of a fact table is usually a composite key that is made up of all of its foreign keys." (Oracle Corporation, 2006, p. Glossary-6)
information	"Data are defined as symbols without meaning...But put into a context, we can give them a meaningful interpretation...we " then "achieve information. We see that in order to interpret information we need a context. Information interpreted in a context by a human being is thus considered as knowledge." (Flensburg, 2004, 182)
job execution environment (JEE)	PDP jobs are usually executed in a JEE. A user or system event transmits the parameters of a data package, which need processing, to the JEE. The JEE identifies the correct production step (C_x), forwards the parameters and starts C_x. Such a production step C_x can raise events with new commands for the JEE to start other jobs (e.g. C_{x+1}). After finishing processing, C_x informs the JEE about success or errors by its exit code. The JEE notices this free server resources and allocates waiting jobs to it. For example, a JEE can be a (commercial) job scheduler.
master data	Master data, also known as reference data "...is any kind of data that is used solely to categorise other data found in a database or solely for relating data in a database to information beyond the boundaries of the enterprise" (Chrisholm, 2001, 3). Master data is the auxiliary material with which the incoming periodic data is compared. Master data, for example in market research, can be the item identification or brand.
milestone chain	A single milestone can have one or more predecessors and successors. These connections result in a net-like structure, which in this thesis has been called a *milestone chain*.

milestone, classic	A *classic milestone* is used in project management. It represents an activity with a due date but no duration time. Milestones are usually assigned after important project sections. Classic milestones have predecessors and successors (Burghardt, 2002).
milestone, context-aware	A *context-aware milestone* is a classic milestone which is enhanced by using the following assigned production information: - dimensions (see description of dimensions in this glossary) - progress information (e.g. 50% complete) - state information (e.g. complete, manual complete, active, delayed, successor available, ignored, etc.)
non-isolatable / isolatable product parts in goods production	Parts which can to each time be identified and be removed from a product part are isolatable. For example, a screw in a car can always be removed and accordingly is isolatable. If liquids for example, are mixed together in the chemical industry, they cannot always be separated afterwards. These liquids are non-isolatable.
non-isolatable product parts in periodic data production	The data packages in PDP are non-isolatable. The reason is, after an aggregation, the source data sets can no longer be easily identified. This circumstance is intentionally desired to allow for example, anonymous end reports.
periodic data	The periodic incoming data is collected in intervals from the different data sources. This data includes facts such as for example, sales values.
periodic data production (PDP) system	Albrecht et al. explain that in building a data production system, immense volumes of periodically gathered data in one specific area are transformed into aggregated multifaceted information (Albrecht et al., 1997, 651-656). In defined intervals, this information is produced and presented in the form of statistical reports and graphics. The repetitive character of information production and presentation is useful to observe the developments of a specific area over a defined timeline. For example, meteorological tracking data, business market developments and statistical analyses for governments are areas to be periodically observed and analysed. PDP systems are the IT support for PDP. PDP systems are a mixture of traditional production and data processing systems.
periodic data production management (PDPM) system	A PDPM system can be defined as IT-support for planning, monitoring and controlling the PDP processes. It is a decision support system which delivers information in order to achieve production optimisation goals. These systems aim at the computerized supervision of timing, costs and resources. The PDPM system works on top of PDP system and observes the production processes.

predecessor	A predecessor of a milestone is a milestone that belongs to a checkpoint one less than the milestone itself.
production intensity	Identifying the *production intensity* means to identify production critical days. Production critical days are days with high loads for the production facilities and workers.
production job	To process a data package at a production step, is called a *production job*. More precisely, a production job comprises that one ore more data packages are processed at a production step which produces one or more new data packages as output.
production step in periodic data production	A production step is a program in PDP which is called to process production jobs. Production steps process input data packages into output data packages. These programs can, for example, include aggregating, separating or duplicating data.
separation	Separation is the reverse operation of aggregation. Separations are database operations such as divisions or pro-rating.
successor	A successor of a milestone is a milestone that belongs to a checkpoint one greater than the milestone itself.

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(Titles of German references are translated into English by AS. Translations are mentioned in square brackets)

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Appendix A: Initial approaches

The initial approaches presented in this appendix are early conceptual design studies for PDPM systems, but where rejected for prototype implementation. As they have been investigated during this research project they are provided for overview and demonstrating early design discussions. The three initial design studies are a hierarchical multi agent approach (see section A1), a Petri net-based approach (see section A2), and a web service-based approach (see section A3).

A.1 Hierarchical multi agent approach

One of the first initial ideas for a PDPM concept was to establish a *traffic-light* to indicate the status of PDP. As such a traffic-light needs to have decision-making functions, because it must decide autonomously to change its colour, the idea was to design a multi agent system for PDPM. In this section this concept is described and discussed.

Concepts
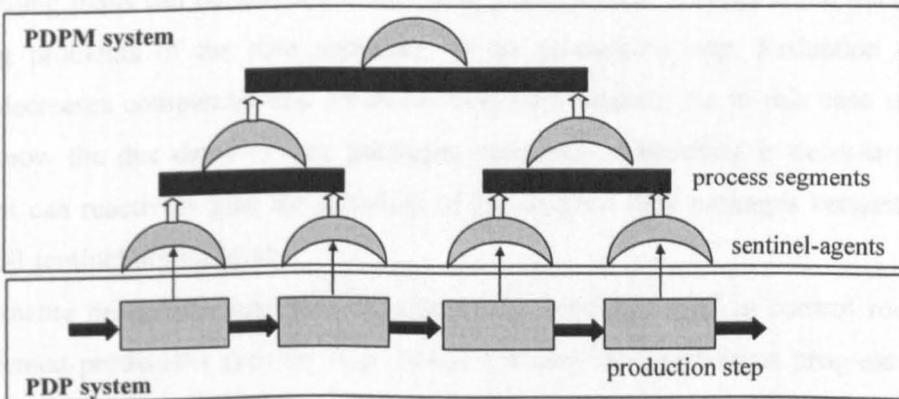
Figure A.1: Hierarchical multi agent system for PDPM

Sentinels for observing PDP: An agent is used in this concept to represent a sentinel for a production step in PDP (see figureA.1). The sentinel agents can be based upon the model of multi agent systems. The usage of sentinels is a proven concept in research as similar approaches have been introduced. For example, in (Klein & Bar-Yam, 2001, 9-12) sentinel-components have been used to handle emergent dysfunctions during run-time in open peer-to-peer systems. Such a sentinel for PDPM controls the assigned production step and understands the type of data package the production step processes. Each production step owns an input queue where data packages that need processing are queued. One guiding idea is that sentinels can change the priorities of data packages in this

input queues to prevent delayed production. In this case sentinels need to know the duration times and due dates of data packages. If the duration time or the due date will be exceeded or if the production steps are not processed error-free, the sentinel notifies its hierarchical superior sentinel. A sentinel, which has several underlying sub-sentinels, weights incoming different messages by rules (which need to be introduced) and informs its superior sentinel if necessary.

Hierarchy for mapping organisational structures: An easy differentiation between process segments (e.g. world-wide distributed departments) is supported by this hierarchical agent organisation, and specific information for user groups can be distinguished (e.g. information for higher management or for operators).

Guaranteeing system health: To ping a production component for health surveillance, public variables in the production step's code could be queried. The sentinel would then be able to read these variables to get knowledge about the completion degree of the currently processed data package and the health state of the controlled production step. Hanging production steps can be identified.

Planning possibilities: The sentinels can host job scheduling units. The problem of big scheduling plans can be reduced in this case, because each sentinel could manage the scheduling problems of the data packages for its production step. Reduction of plan volumes decreases complexity and promotes also performance. As in this case sentinels need to know the due dates of data packages, reactively scheduling is necessary. Each department can reactively plan the schedule of its assigned data packages because of the hierarchical sentinel organisation.

Showing production progress: Similar to the approach used in control rooms for sensor-oriented production systems (e.g. power stations) the production progress can be provided as a traffic light control. In unsatisfying or exceptional situations the sentinels show red or yellow. They report green when there are no production problems.

Evaluation of this approach

This concept is evaluated by using the issues presented in section 4.4 to introduce its dead-ends and problems and to demonstrate why it has been rejected for prototyping.

1. *Evaluation regarding the problems arising due to coping with PDP specifics*

- Sentinels do not have to cope with changing product keys as each sentinel only observes one production step.
- This also obstructs measurements of important key performance indicators like for example throughput times. The basis for key performance indicators might be

suspect and difficult to proof because they are highly dependent from the decision rules introduced to the sentinels. Decision rules are hard to establish as in many production situations manual decisions can be a better choice.

- Moreover, there are no overviews for past or future production. Thus, this concept can be compared to life-cycle management, which is not sophisticated enough for PDPM.

2. *Evaluation regarding the difficult observation of the data flow*

- The problem of how to identify the progress of an end-report remains as predecessor and successor relationships between data packages are not adequately tracked.

- Sentinels lack not only the dependencies between data packages but must also have knowledge of their content for supporting statements of production progress. If not, it would not be clear which data are processed to which degree and lacking data packages cannot be recognized. Sentinel programming would then be expensive and resource-consuming as they need nearly the same knowledge as the programs of production steps.

- Introduction of new or changing production steps would led to a comparable high effort for the matching sentinels. Introducing and changing agents would still be a manual task. If additionally process segments change, sentinel organisations need to change as well. A high number of sentinels thus complicates maintenance.

3. *Evaluation regarding planning problems*

- This concept does not offer any new ideas for automating the planning of easing the handling with the numerous deviations. No different scheduling concepts advance the discussion for strong PDPM.

- In every case agents do not prevent re-planning as this would remain to a large degree a manual task. Deviation needs to be manually handled.

4. *Evaluation regarding ignoring the repetitive character in PDP*

- On the one side agents run fully autonomously. On the other side the system load can increase and slow-down production due to the additional load of these agents.

- Production optimisation is supported by automated surveillance of production step's duration times. As the sentinels do not provide solutions for the reduction of waiting times this is not efficient enough.

5. Evaluation regarding the difficulties with this distributed environments

- As PDP is parallel organised to support optimisation, sentinels would have to observe several instances of the production steps. Consequently, the sentinels tend to be complex due to the need for concurrency.

- The parallel production complicates the observation process of sentinels as production step instances can be distributed. The sentinels would need an additional management if they were expected to be able to provide their health.

A.2 Petri net-based approach

Due to the fact that data processing management in form of WFM often uses Petri nets as a well-established base, the attempt was logical to investigate Petri nets for PDPM. In this section the description of the concept follows, that was created with these Petri nets techniques to establish computerized PDPM.

Concepts
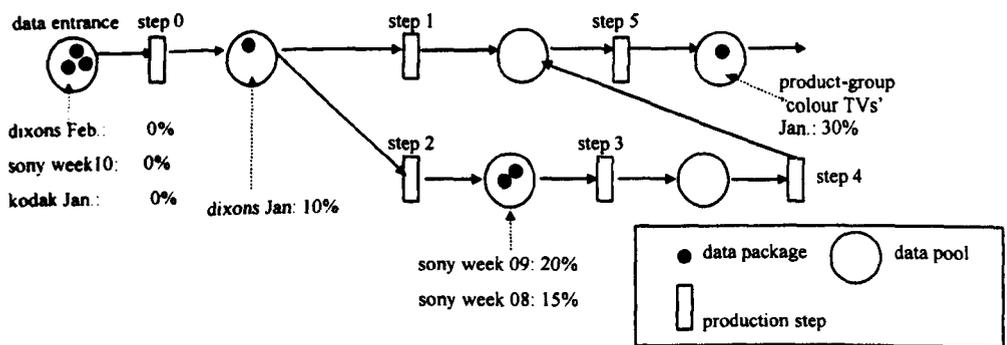
Figure A.2: Market research example of a life-cycle management with Petri nets for PDPM

Life-cycle management by clever interpretation of tokens, places, and transitions: The many different net-structures which can be described by Petri nets and their mathematical correctness are of interest for PDP. Life-cycle management for PDP can be enabled by interpreting tokens, places, and transitions. Tokens represent data packages, and places can be seen as pools where data are gathered. Transitions are equal to the production steps. In figure A.2 an example of a possible PDPM for market research demonstrates the type of overview which can be gained. The workflow and the flow of the data packages is visible in this example. Data packages are inserted at the data entrance and are represented by tokens. Modelled with high-level Petri nets each product identification of tokens is represented by a different colour, but to support a better understanding in figure A.2 text instead of colour is used. If new data packages are created by aggregations and separations, as shown in the token after step 5 (e.g. product-group

'colour TVs'), a new colour for this new token needs to be assigned. Each token has an assigned completion degree to indicate the progress a data package has made in processing in relation to the finishing of its assigned end-reports. The completion degree can be estimated by logging the average duration times per repeated data package. These average duration times can be additionally used as thresholds for planning and indicating system health.

Guaranteeing system health: The display of completion degrees and the consideration of average duration times indicate whether production problems exist or production progress is adequate. As production steps usually log production errors, and production operators need to control the progress anyway, this can be sufficient.

Planning possibilities: Data orders with deadlines are used to indicate when data packages must be inserted. They are derived from end-reports and are backwards propagated to the data entrance. If the aggregations and separations of data packages are known in advance, the average duration times can be added to these deadlines for preparing plans for estimating the whole cycle (e.g. by using JS algorithms). The delta between planned and current states allows the measuring of productivity. Plans need to be recalculated when deviations arise or data order deadlines change.

Showing production progress: The completion degree shows the progress for each data package.

Evaluation of this approach

The introduced concept is evaluated by using the issues presented in section 4.4. This concept was not considered for further research due to the following problems:

1. Evaluation regarding the problems arising due to coping with PDP specifics

- To use Petri nets means to gain life-cycle management of PDP. However, the fact that product identifiers change complicates the overview as it would not be clear for a user, why and when new tokens where created due to aggregations and separations.

- Key performance indicators and production overviews need to be invented in this approach.

2. Evaluation regarding the difficult observation of the data flow

- Current production state tracking seems to be possible in real-time. However, polling the production steps steadily for progress can cause slow-downs in production.

- The tracking of past production is not supported. Moreover, it is not proven if the tracking of future production is adequately possible as this depends highly on the frequency of deviations. A high number of deviations could lead to not manageable re-calculation of plans.

- Predecessor and successor data packages cannot be easily identified. One possible solution would be to store lists of product identifiers for data package's pre- and successors. However, these parentage lists are quickly becoming non transparent when several aggregations or separations where carried out. Another possibility would be to split or merge tokens, but there is still no adequate formal representation in the mathematical schema of Petri nets. The only possibility to track the current data flow would be to introduce a new token and to change the colour of this token. However, changing the colours and new colour assignment is complex and might be unserviceable. Users are not enabled to adequately track a change in colours.

- The researchers in this area do not recommend applications in large, complex, and dynamic fields. The question remains, if an overview can be offered when thousands of data packages need to be displayed at once.

3. Evaluation regarding planning problems

- Due to the dynamic production behaviour and the deviations, the calculation of completion degrees, in relation to end-reports assigned, is hard to gain. These assignments can frequently change, and re-calculations would be the consequence. Users would not easily be able to understand or to track completion degree changes and the completion degrees reliability might not be sufficient. A large number of deviations complicates the re-calculation of completion degrees and of production plans.

- The creation of plans is complicated because the product identifiers of data packages change and assigning end-report is thus complex. Plans need to be calculated by using these assignments and the average duration times. Deviations complicate plan calculations in time.

- Frequent re-calculations of the plans would be necessary and lessens the chances for up-to-date production overviews.

4. Evaluation regarding ignoring the repetitive character in PDP

- Optimisation can be reached by improving regularly the average duration times. A problem for providing reliable duration times are seasonal fluctuations. They lead

to incorrect duration time measurements.

- Optimisation by waiting time reduction is not sufficiently supported in this concept as the focus lies on duration time measurements.

5. *Evaluation regarding the difficulties with this distributed environments*

- Petri nets have no problems with distributed and component-based system support. They are useful for handling parallelism and concurrency. Whether networks separate places and transitions is not important for implementing such an application, for example, by using a multi agent approach. However, such agents would need additional health control to ensure their availability.

A.3 Web service-based approach

The approach introduced in this section is based on the guiding ideas of service-oriented architectures, which are discussed with high interest today (e.g. Mohan, 2002, 1-5). The idea of this approach is to create and forward 'processing tickets' from one production step to the next by using web services technology in order to achieve punctual PDP. Thus, PDPM is based on the principle of service-based processing. In this concept a level-based system design concept is used. It has been published in (Schanzenberger & Lehner, 2002; Schanzenberger & Lawrence, 2003, 69-76).
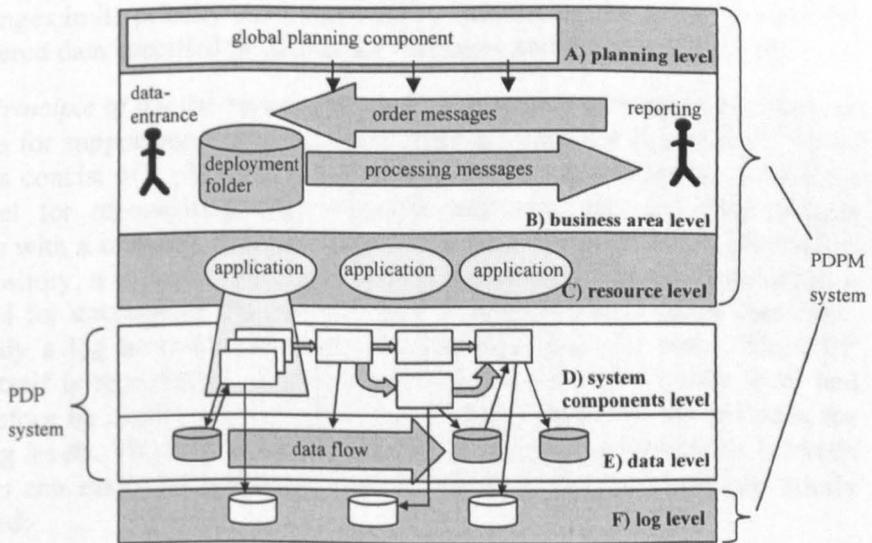
Figure A.3: The web service-based approach for It-aided PDPM (Schanzenberger & Lehner, 2002)

Concepts

Principle of a service based processing: The original idea is based on using web services for message processing. The control of production is supported by exchanging messages between the production steps. A decoupling

between the production steps is achievable by asynchronous message handling. Two different message types are to be applied:

- *Data order messages:* specify the data which need to be processed for satisfying an end-report's calculation base. Thus, such a data order is propagated backwards from the reporting to the data entrance. In this approach not only the data entrance receives data orders, but also all participating business areas (e.g. departments). A data order contains content-, time-, and production-based information.
  - o Time information: One data order has a specific deadline. The deadlines are calculated based on duration-time estimations.
  - o Content-oriented information: Specific data packages are selected for satisfying an order.
  - o Production information: A completion degree in percentage for showing production progress is assigned. It is adjusted appropriate to the production plan. The order message includes the planned and the actual state of an order. On the one hand, this gives the user of the PDPM tool the possibility to query the current state of one order. On the other hand it gives resources additional information to prioritise orders.

  Data order administration is centralised and data orders are forwarded to the business areas (see figure A.3). Each business area is only able to cope with one type of product identifier. The data order administration therefore needs to deal with the changing product identifiers and to produce data orders for each type of the product identifiers.
- *Processing messages:* inform a successor production step about a pending job. A processing message is used for the control flow management and is exchanged between productions steps. It is also used for scheduling as changes in its priority can be caused by calculating the delta between the ordered data specified in data order messages and the processed data.

Principle of a level-based approach: The system concept is divided into six levels for supporting a clear functional partitioning (see figure A.3). These six levels consist of a planning level for data order administration, a business area level for representing organisational structures and grouping process segments with a common deadline, a resource level for providing a production step repository, a system component level for keeping all program modules, a data level for uncoupling the periodic data to support independent data flow, and finally a log level for providing a calculation base for plans. The PDP system itself is represented by the system-component and the data level and can therefore be clearly divided from the PDPM system, which includes the remaining levels. The interfaces and the communication requirements between the levels can easily be identified. In the following the six levels are briefly introduced:

(A) Planning level (global over all business areas): Data order administration is centralised to serve as a global instrument for planning. Data orders are derived from the end-reports and backwards propagated to each business area. The purpose of data order forwarding is to publicize for each business area a specific deadline. User can intervene manually in deadline planning, but usually deadlines should be discovered by a comparison to past production scenarios.

(B) Business area level: A business area represents a production step or a correlated group of production steps with one common deadline. It can additionally represent organisational structures (e.g. sub-departments) and includes basically an information system. In this information system a deployment folder is introduced. In this deployment folder all resources are registered which belong to this business area. Incoming data order messages are forwarded to all participating resources. Data orders can consequently support work-lists for resources. According to the deadlines in data orders, priority changes in processing messages are possible.

By using web-service terminology the 'business object' which represents a business area provides two functionalities:

- accepting data order messages and forwarding them to participating resources.
- providing control flow information with a deployment folder. Resources are able to find their successor production steps in this folder. It includes all information about the ramifications of production steps. An UDDI (i.e. Universal Description, Discovery and Integration (UDDI, 2001)) can represent this deployment folder.

(C) Resource level: The resource level hosts all resources of a business area. Possible resources can be:

- Work lists: Incoming orders are published as a kind of 'work list' and can thus be forwarded to one or more staff members.
- Applications: An application is a logical representation of a production step and of its corresponding software-module.
- Workers: Responsible persons for processing production steps can be identified.

(D) Level of system components: The system component level includes all software modules of the corresponding production steps. Multiple instances of production steps are possible. These instances can be processed on different servers. Resources from the resource level are controlling these instances. Each instance queries its successor production step by using the deployment folder. After identifying this successor production step the instance sends a processing message to it to inform about a pending job.

(E) Data level: The data level organises the data flow of the data packages and offers transmission possibilities between different storages. Each production step is logically assigned to specific data storages. Included in the data level is thus transactional protection for proper production step's instance handling.

(F) Log level: Web-services are used for logging the following information:

- Service-log: It contains health information of production steps and production errors.
- Application-log: This log includes specific information of the applications. For example, the amount of data sets, the run-time information assigned to data packages and production steps. The application-log is therefore the basis for the planning level. Which data packages are processed can be presented via web GUIs.

(Schanzenberger & Lehner, 2002; Schanzenberger & Lawrence, 2003, 69-76)

Evaluation of this approach

This concept is compared to the issues presented in section 4.4. This approach has not been considered for the prototype as the following problems have been identified:

1. Evaluation regarding the problems arising due to coping with PDP specifics

- Due to the need of the data order administration to handle the high complexity of changing product identifiers for the whole process, this concept has been assessed as too complex for the prototype. The reason is, it has to be avoided that data order creation is as complex as PDP itself.

- Key performance indicators and production overviews need to be invented in this approach.

- Forwarding the data orders to the business areas would lead to a high additional communication effort. High numbers of run-time deviations would immensely increase this communication effort. This communication needs again computerized supervision to deal with its own delays and errors. However, a management system for managing PDPM is not advisable.

- Web services and service-oriented architectures themselves do not help to solve any of the PDP specific problems, as both can only be seen as an enabling technology for PDPM.

2. Evaluation regarding the difficult observation of the data flow

- Data flow tracking is not adequately represented in this concept as predecessors and successors of data packages cannot easily be identified.

- The actual database for an end-report is not anymore provable. The data flow of the past, current, and future production is not adequately traceable. Only production state checking of current production is possible as the delta between data orders and processed data at each production steps can be queried.

3. Evaluation regarding planning problems

- If the processing, re-calculating, and forwarding of data orders is delayed there is a risk to also delay PDP. If a high quantity of run-time deviations is expected, the risk to delay PDP increases. However, the aim of PDPM is to ensure punctual PDP and not to counterproductively increase the risk for production delays.

- In this concept planning is provided by backwards propagating data orders with deadlines to business areas. This is also possible in advance to inform about pending data orders. The advantage is there are no serious job scheduling problems as sorting data orders by deadline informs about priorities. The disadvantages are, there is an additional effort to match the data orders and processing jobs for comparing their data overlapping adequately.

- As processing jobs do not have information about their predecessor and successors relationships (i.e. the production steps just send processing messages without knowledge which previous steps have been processed or which steps will be processed next) users cannot adequately track whether the end-reports processing was correct.

4. Evaluation regarding ignoring the repetitive character in PDP

- Previous data order deadlines are used as pre-settings in the next production periods. However, it is not ensured if these deadlines are correctly optimised as manual intervention is allowed and the duration times of past production jobs cannot easily be correlated for this calculation as the correlation is not stored. Storing the correlations cannot be recommended due to the expected additional data quantities.

- Calculating frequently the delta between the ordered data specified in data order messages and the processed data cannot be recommended for high data quantities.

5. Evaluation regarding the difficulties with this distributed environments

- Web services are an excellent technological solution for bridging the gaps between a world-wide data distribution. Accordingly, there are no particular problems to use such an approach in a distributed environment.

Appendix B: Context of the practical research – the prototype environment

During this research project a prototype of a PDPM system was implemented for the leading market research organisation GfK Marketing Services. In this appendix the business processes and the infrastructure of their PDP system are described to advance the understanding of this application area, of the prototype, and the outcome of the development and implementation work. In section B.1 the market research environment is discussed. GfK Marketing Services and its retail and technology panel is introduced. The infrastructure of their software systems are described in section B.2. This group of software systems constitutes a distributed and component-based PDP system.

B.1 The market research environment

It is necessary to base marketing decisions on knowledge. Market research organisations offer business information services that provide this knowledge for their client companies. The services are based on extensive market research. Market research is the collection and analysis of information. Examples of market research results are:

- information about consumers
- information about competitors
- information about the effectiveness of marketing programs
- answers to questions about the feasibility of new businesses
- information about the interest in products
- development of strategies to improve customer services and distribution channels

Market research is a systematic and impartial process that is based on proven statistical methods which observe market behaviour and company environments. In this section the aim is to introduce PDP processes in market research on the example of GfK Marketing Services.

Section B.1.1 introduces the market research company GfK Group. The prototyped PDPM system has been developed for one of its main divisions, the Retail&Technology division, also referred to as GfK Marketing Services. The panel methodology and the retail audit panel produced from GfK Marketing Services is outlined in section B.1.2. In section B.1.3 the PDP business processes for this market research environment are introduced. This is to advance the understanding of PDP processes with a real-world example.

B.1.1   The market research company GfK Group

In this section, structure and organisation of market research organisations are described. This information industry sector is introduced on the example of GfK Group.

Established as the first German market research organisation in 1934, GfK Group is one of the world's leading market research companies. GfK Group employs more than 7.600 full-time staff members and has achieved sales of around 990 million Euros in 2004. Today, their global network operates in approximately 63 countries on five continents in about 130 subsidiaries, branches and participations. The business information services offered to their customers provide the knowledge that industry, retail and service sectors and the media need in order to make their marketing decisions. Their business information services are delivered to major global players in the consumer goods, services and healthcare industries. In five divisions the data for the different business information services are produced (see figure B.1). The divisions Consumer-Tracking and Retail&Technology offer their services by using the panel method, which supports periodic information deliveries (cp. section B.2.2).

Custom Research Sales (%): 37,9	Media Sales (%): 9,4	Healthcare Sales (%): 10,3
Retail & Technology Sales (%):28,2	Consumer Tracking Sales (%): 14,2	panel research
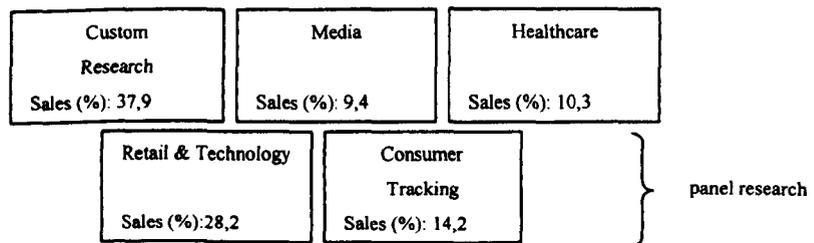
Figure B.1: The five business divisions of GfK Group

The prototype of the PDPM system is implemented in the Retail&Technology division. This division carries out continuous and systematic monitoring of sales regarding consumer durables and services. Movements in these markets are reported for all the relevant sales channels and forms of retail distribution. All subsidiaries of GfK Group that participate on this retail panel are referred to as GfK Marketing Services. Approximately 250 members of staff are working in the central branch in Germany, Nuremberg. In addition, in more than sixty countries branches are located which produce the information services and labour towards a high coverage for this international reporting base.

B.1.2   The retail audit panel

This section provides the description of a 'retail audit panel' and the 'panel method'. An example is the retail audit panel of GfK Marketing Services. It is used to describe all the business processes represented in the PDP system. To be able to design an effective PDPM prototype, the business processes of the PDP system have to be studied.

"Definition of the panel methodology: Panel methodology requires a stable or dynamic body of survey units, which are regularly surveyed at discrete intervals, using either observation, interview or experimental techniques. The subjects of such surveys may or may not change. "

(Redwitz, 2003, chapter 3, 4)

Koschnick defines panel research as an established method of data collection and data analysis. The principle of panel research is to investigate the same sample at different times for the same variables (Koschnick, 1987, 623). The advantage of a panel is that changes of each single panel-variable are measured during a time period by using the same stimuli and thus both individual and aggregate analyses are possible. Panel research differs from other methods like trend-, prediction- and repeated inquiry- investigations because usually survey units and panel-variables do not change.

"The term retail audit research defines the use of a panel to collect concrete facts, using a homogeneous system. Here the data is either collected by full-time trained field staff working for a market research company, or by the collection of information via an electronic medium. The data is collected at regular intervals from a panel of retail outlets, which are selected, and if necessary modified, to represent the current structure of the universe of relevant channels of distribution."

(Redwitz, 2003, chapter 3, 9)

The retail audit panel specialises in observing retail outlets, the survey units, at regular intervals. Those intervals can vary from weekly, to monthly to yearly intervals. The survey subjects are defined groups of products (referred to as product-groups). Thus, the retail panel is an instrument of market research for the observation of the retail sales by continuously collecting and analysing quantitative data about structure and development of different product-groups. (Berkoven et al., 1991, 140). Accurate assessment of sales achieved by retail outlets can be provided (Jobber, 1998, 149-150).

A retail audit panel should fulfil the requirements of accuracy, completeness, up-to-dateness and comparability. Generally, each period the same retail outlets are observed. However, panels need to be updated to reflect changes in market conditions such as new forms of retail.

Collected are variables as, for example, stock sizes, purchases and sales prices for all units of the product-groups (e.g. products, brands, packaging sizes, bundles, details, etc.) (cp. Kumar et al., 1999, 138). The intention is to gain insight in dynamic developments of market segments, product and price groups, and to enable static quantitative analyses of sales data to a specific time period. Identifiable are short-term and

long-term changes in the observed markets. An example for such an analysis is shown in figure B.2.Customers of market research organisations purchase such analyses in form of reports. These analyses are the empirical base for the management decisions in the customers' organisations. The purpose of these analyses is to support planning, monitoring and controlling of their marketing strategies.
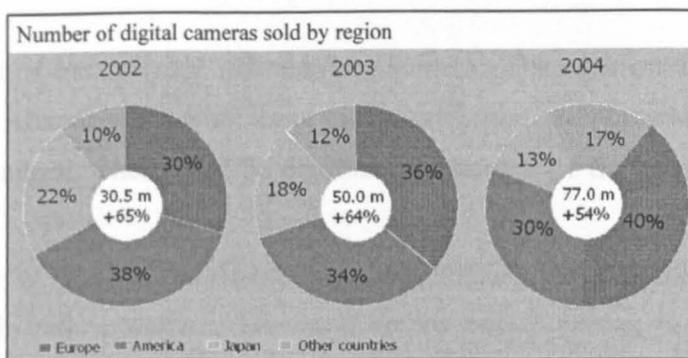
Figure B.2: Example of a statistical report from a retail audit panel (GfK Marketing Services, 2005)

B.1.3 The periodic data production process for the market research environment

The PDP processes of the GfK Marketing Services' retail audit panel which the prototype of the PDPM system needs to control can be described as follows:

Stages for creating the retail audit panel

Figure B.3 depicts the basics for the production of the retail audit panel. The stages 1 to 4 are the initialisation of the panel, whereas the stages 5 to 10 are periodically repeated to monitor the retail outlets over a defined timeline. Thus, the latter stages are PDP business processes. Processes which can be supported by using a PDP system are the stages 5 to 9 (cp. section B.2.3). Stage 10 needs no further IT support as in this stage results which are derived from the finalised panel data are manually presented to customers.
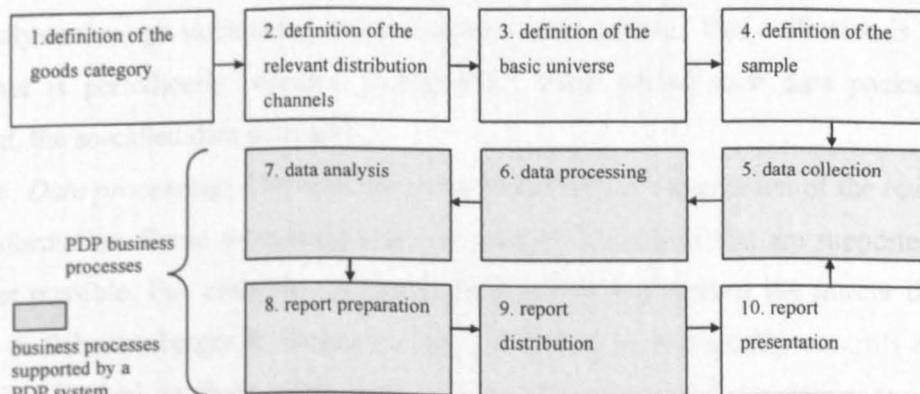
Figure B.3: Overview of the stages for creating a retail panel (Redwitz, 2003, chapter 3, 14)

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1. *Definition of the goods category:* At the beginning of the process the survey subjects are defined. This is to identify the goods categories and to particularise the subjects by defining the product-groups which are to be monitored within each goods category. For example, goods categories are major domestic appliances, photo, or consumer electronics. Examples of product-groups are refrigerators, digital still cameras, or colour TV's.

2. *Definition of the relevant distribution channels:* For each product group the relevant distribution channels in which these goods categories are physically offered for sale are to be determined. Therefore, the distribution channels of the manufacturers are queried.

3. *Definition of the basic universe:* The retail outlets that represent the market define the so-called 'basic universe'. The retail outlets, which belong to the identified distribution channels, are determined at this stage. This is called 'to create a basic study' where structural features and assortment of retail outlets are classified. Secondary research sources, such as customer databases of manufacturers or purchase tax statistics of regional authorities, are used for this identification. This process is supplemented with questionnaires in the candidate outlets.

4. *Definition of the sample:* As the observation of the complete basic universe is usually not cost-effective for a continuous monitoring, a subset of the retail outlets needs to be specified as a significant sample. This is done by using the 'quota-procedure'. Instead of using an uncertain random sample, the quota-procedure supports outlet selections which are intentionally chosen, by not exceeding a specified maximal sampling error. Its advantage is that the number of retail outlets to be observed is minimised as the heterogeneity of retail outlets can be compensated by using partitioning (cp. Redwitz, 2003, chapter 4, 17-32).

5. *Data collection:* The collection of the audit data in the retail trade is done by field analysts through stocktaking or by electronic data exports. This collection is the first stage that is periodically repeated during PDP. Each period such data packages are collected, the so-called data deliveries.

6. *Data processing:* The data has to be processed for the creation of the retail audit panel information. Some processing steps are manual operations that are supported by IT wherever possible. For example, checking the periodic data against the master data (cp. Kirsche & Schanzenberger & Baumann, 2005, 449-453) or data quality controls are such operations. Typical database operations such as aggregation and separation are used to

condense or multiply the desired information. Finally, the data are extrapolated by using statistical methods. These are the multiplication of the sales, purchases and stock values of each retail outlet with an specified factor (i.e. raising factor) to be able to raise the accuracy and to minimise the sample error. For example, the effect of peaks in sales values can be decreased by manually reducing the raising factor for an extrapolation.

7. *Data analysis:* Analysts are examining and investigating the processed panel information. Their main objective is to assess market behaviour and to extract trends. Interesting developments in the observed markets are identified.

8. *Report preparation:* In each reporting period standard and international reports are generated out of the panel data. Individual customer reports are prepared as well to present analysis results for specifically asked questions. In addition, the different report formats are produced according to customer expectations. Report formats can vary from simple tabular statistics to advanced business graphics. Specific chart tool formats are used or even XML files to store the reports. (cp. Christ, 2001, 69-98).

9. *Report distribution:* The completed end-product 'report' is then distributed to the customers of this information service. The reports are sent via post mail or electronic transfer.

10. *Report presentation:* The report results are usually presented by experts during customer visits. This is important because only interpreted reports are helpful for the discussion of marketing strategies in the customer companies.

Periodic repetition in PDP processes

As shown in figure B.3 the PDP processes include stages which are periodically repeated. The repetition intervals in a PDP process vary for different data deliveries, product-groups and end-reports. This means, retailer outlets deliver data at different intervals, such as weekly, monthly, bi-monthly, etc. The production of each of the numerous product-groups has its own deadlines: weekly, monthly, bi-monthly, etc. The deadlines of delivering end-reports to customers are fixed in contracts between the organisation and the customers. Once again, end-reports can be created in different intervals. Although a PDP process has its peaks and valleys, it is a continuous process. The different production steps in the PDP system are permanent in use due to the various data packages to be produced world-wide in different intervals. Consequently, a push- and pull-mechanism between production and reporting can be identified. Data are 'pushed' into the PDP system, produced and stored. Reporting 'pulls' the produced data at different times for the generation of end-reports. The continuous process and the various intervals that

need to be handled complicate particularly the time management for this type of PDP processes.

B.2 Infrastructure of the software systems

The StarTrack workflow

In figure B.4 the central modules of StarTrack and their respective position within the value creating chain are shown. The modules reflect the company's PDP processes through its IT. They cover all areas of the production process and provide international access via web technology.

Master Data Management System: This is a module for the integration of master data of shop, product and client key data. It provides the master data as information source for all the other modules.
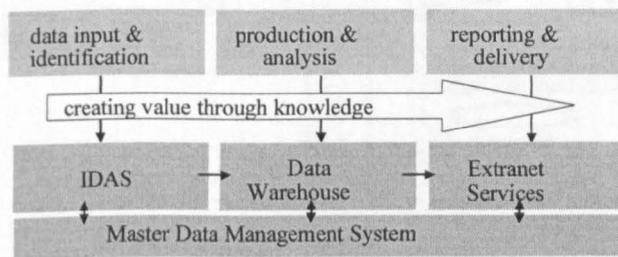
Figure B.4: Central modules of the StarTrack system (Redwitz, 2003, chapter 5, 5)

IDAS (International Data Acquisition System): All modules for data collection belong to this system. It deals with different data formats of the raw data which are used by retailers, the identification of unknown items, the separation of known items, and condensing and storing this periodic data (see section B.2.1).

Data-Warehouse: All modules concerned with reporting are subsumed under the umbrella term 'Data-Warehouse'. This includes data quality controls, filling the reporting base which is in technical terms a data warehouse, data extrapolation and preparation of reports with reporting tools (see section B.2.2).

Extranet Services: The modules for the end-report distribution to customers belong to the 'Extranet Services'. The distribution is organised via web-servers for downloading reports, via e-mail or via post mail (see section B.2.3).

The production steps incorporated in IDAS, the Data-Warehouse as well as the production steps incorporated in the Extranet Services form the PDP processes. These PDP processes are planned, controlled, and monitored from the PDPM prototype. Thus, they are of interest and are described in more detail in the following sub-sections.

B.2.1   Data acquisition

The PDP system of GfK Marketing Services organises the data collection and the alignment to its product master via the IDAS sub-system (see figure B.5 adapted from figure B.4). Its functionalities and features are described in this section.
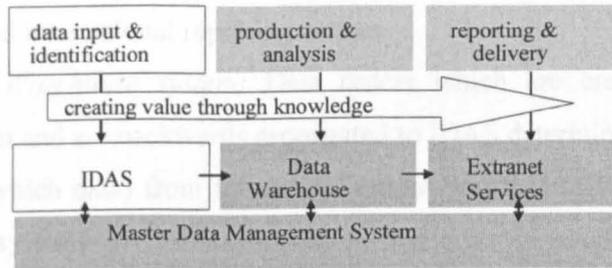
Figure B.5: IDAS - the data collection in StarTrack (Redwitz, 2003, chapter 5, 5)

IDAS incorporates the following production steps of the PDP system (see figure B.6):
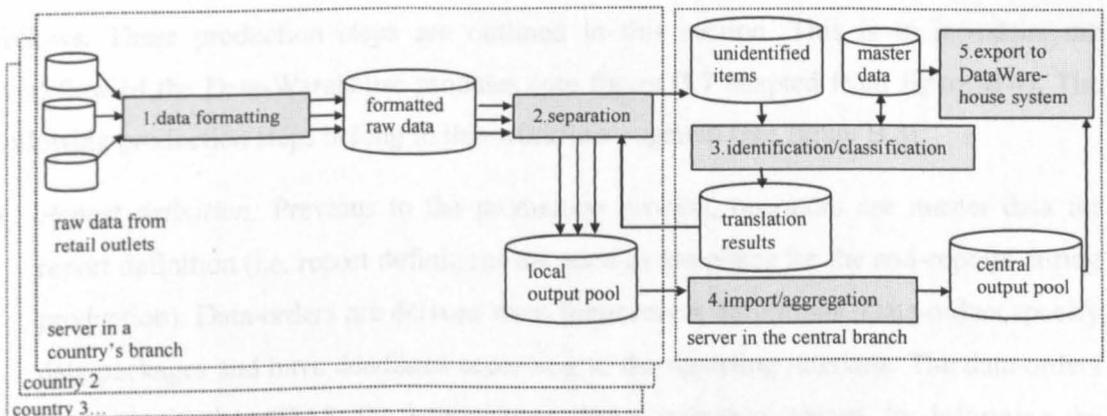
Figure B.6: IDAS workflow (adapted from Redwitz, 2003, chapter 5, 22)

1. *Data formatting:* Sales data packages from retailer arrive as raw data in many different formats and in different intervals at the data entrance. For a better comparability, the first step is to convert raw data into a standard format.

2. *Separation:* The next production step is to separate items (i.e. single data sets) in identified and unknown items. All items which can be identified are condensed and transferred into the local output pool. The unknown items are separately treated as described next.

3. *Identification/classification:* All items which include unknown attributes are separated and transferred to the central servers for processing. If totally new products have been sold in retail, these items need to be classified (e.g. product-group assignment). The newly classified products complement the master data. If the classification of the products exist, but, for example, the item text is non-ambiguous, the item has to be identified via user interaction. The translation results are sent back to the local server where the original unidentified items directly flow to the local output pool. These

translation results are stored for complementing the automatic separation for the next production intervals.

4. *Import / aggregation:* The periodic data are then imported and condensed from the local output pool into the central output pool. The central output pool is the source pool for all national and international reporting actions.

5. *Export to Data-Warehouse system:* Data orders which are created in the Data-Warehouse system and are backwards propagated to IDAS determine the points in time when data (and which data) from the central output pool has to be exported into the Data-Warehouse system.

B.2.2 Reporting

After data collection, the data extrapolation, analysis and report preparation follows. These production steps are outlined in this section. This is to introduce the workflow of the Data-Warehouse modules (see figure B.7 adapted from figure B.4). The following production steps belong in this workflow segment (see figure B.8):

1. *Report definition:* Previous to the production process, operators use master data for report definition (i.e. report definitions are used as templates for the end-reports during production). Data-orders are derived from these report definitions. Data-orders specify data packages and have deadlines according to the reporting intervals. The data-orders are transmitted to IDAS, the international data acquisition system, for informing the previous workflow segments when data packages are expected to be readily processed.
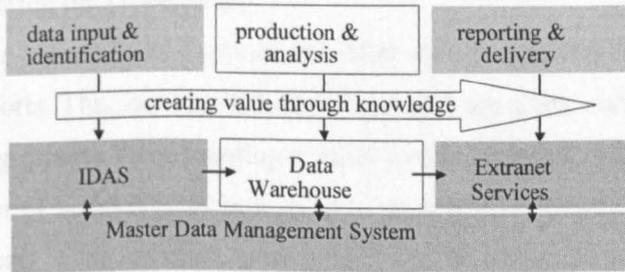
Figure B.7: Data-Warehouse - the reporting in StarTrack (Redwitz, 2003, chapter 5, 5)

2. *Definition of extrapolation:* Reporting intervals differ from data collection intervals. Therefore, the deadlines of the data-orders indicate when the export of the specified periodic data from the central output pool is expected. When the deadline of a data-order is due, the operators send 'load-definitions' to IDAS. Load-definitions are the explicit instructions to export specified data from the central output pool to the Data-Warehouse system. Data-orders and load-definitions often specify the same periodic

data, but can also differ in case of deviation handling (e.g. a retail outlet omits source data or data packages fall below quality criteria).
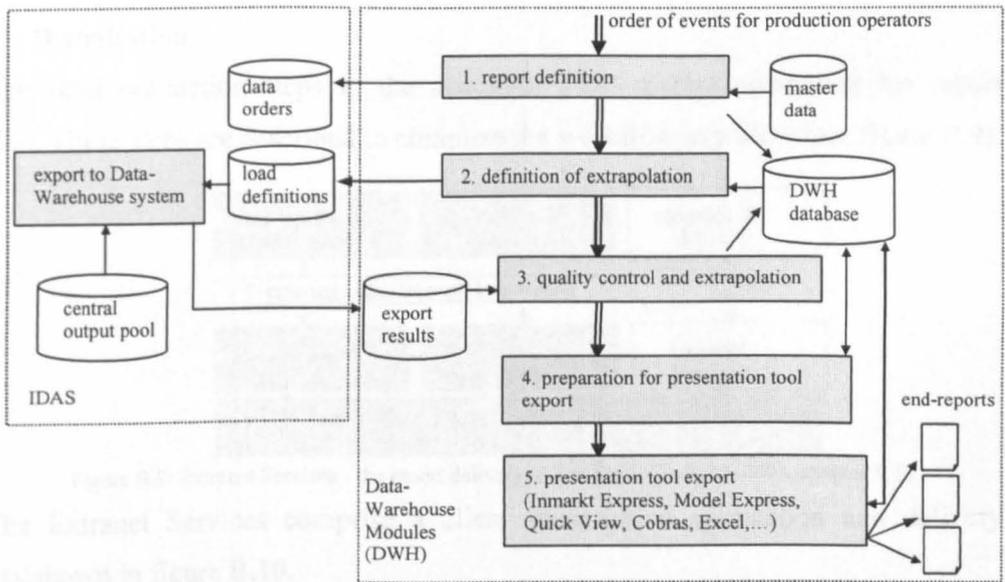
Figure B.8: Data-Warehouse workflow (adapted from Redwitz, 2003, chapter 5, 26)

3. *Quality control and extrapolation:* When the export of periodic data into the Data-Warehouse system is completed, the operators have to determine the necessary data manipulations. Possible manipulations are to extrapolate available periodic data (e.g. determining raising factors or to counter-balance special events in the market) and to compensated unavailable periodic data. These manipulations are the last step of the data quality controls. Finally, the data is manually released to inform latter production steps of completing the processing.

4. *Preparation for presentation tool export:* After data processing is completed, analysts prepare the reports. This includes determining report specifics, such as the report layout such as running reports for presenting market trends in terms of time, standard reports for presentation of various facts in a specific time period, product sales league tables, or report formats such as chart types, title, top headings and side headings. This selection depends on the results of the data analysis which is done in parallel to report preparation. A typical analysis starts at a relatively high aggregation level and identifies significant variations in the data. Variations are then investigated and reported accordingly. The results are standardized report definitions in the form of XML files.

5. *Presentation tool export:* The standardized report definition files are used to export the specified data into different presentation tools. After finishing the export, the presentation tools are used for the visualisation of the completed end-reports. Such

presentation tools range from simple Excel to specialised databases with querying possibilities such as Inmarkt Express, Model Express, Quick View, or Corbas.

B.2.3   Distribution

The final production steps in the described PDP system coordinate the report distribution. These steps are described to complete the workflow overview (see figure B.9).
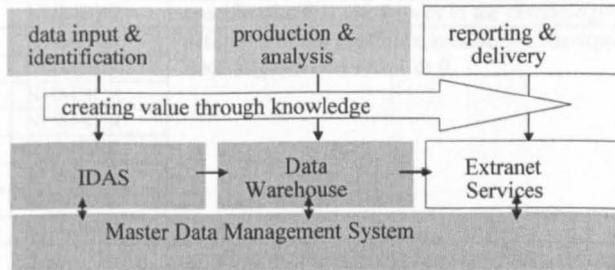
Figure B.9: Extranet Services - the report delivery in StarTrack (Redwitz, 2003, chapter 5, 5)

The Extranet Services comprise a client subscription application and delivery services as shown in figure B.10.
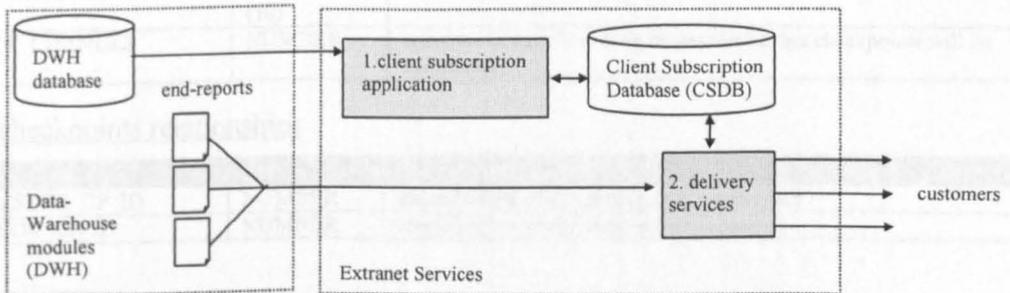
Figure B.10: Modules of the Extranet Services

1. *Client subscription application:* A company internal database holds all information about client contracts relevant to report production. Staff members world-wide can input the customer details, contracts and delivery arrangements.

2. *Delivery services:* Various forms of delivery services are available, such as paper copy, e-mail, FTP or web pages for downloading reports. The report distribution is largely automated in the case of distribution via web pages. In the other cases, the delivery of reports is organised by the staff. Reports are often delivered in intervals to the customers according to contract agreements. To meet the deadlines of deliveries, specified in customer contracts, is a main ambition. Delivery deadlines and the times when reports are completed can differ. This has to be managed with respect to the fact that reports can be sold multiple times to different customers without additional material consumption.

Appendix C: Database schema extract of the prototype

Table: checkpoints

attribute	type	description
CP_ID (PK)	NUMBER	checkpoint identification
CP_NAME	VARCHAR2 (256)	name of checkpoint.
FIRST	NUMBER	specifies the first checkpoint in the chronological order
DELIVERY_PERIOD_FLAG	NUMBER	definition of the possible dimensions a checkpoint has.
DELIVERY_TYPE_FLAG	NUMBER	Each flag can be either 1 or 0.
PRODUCTGROUP_FLAG	NUMBER	
REPORTING_PERIOD_FLAG	NUMBER	
PROFILE_FLAG	NUMBER	
PROJ_FLAG	NUMBER	
TARGET_FLAG	NUMBER	
REPORT_GROUP_FLAG	NUMBER	
PLSQL_FUNCTION_NAME	VARCHAR2 (256)	specifies the name of the function which checks the status of milestones at this checkpoint
LAST_CHANGED_WHEN	DATE	the last date when this entry has been changed
LAST_CHANGED_BY	VARCHAR2 (20)	specifies who changed this entry.
DUE_DATE_STRATEGY	NUMBER	specifies the strategy how planned due dates have to be calculated
CP_SHORTNAME	VARCHAR2 (10)	short-name of the checkpoint
RETRACK_CHANGES	NUMBER	specifies in days how long milestones at this checkpoints will be maintained.

Table: checkpoints relationships

attribute	type	description
PREDECESSOR_CP_ID	NUMBER	identification of the checkpoints predecessor
SUCCESSOR_CP_ID	NUMBER	identification of the checkpoints successor

Table: milestones

attribute	type	description
MS_ID (PK)	NUMBER	milestone identification.
VERSION (PK)	NUMBER	version number of a milestone
CP_ID	NUMBER	checkpoint identification to which the milestone belongs
DUE_DATE	DATE	specifies when the milestone is expected to be due
COMPLETE	NUMBER	status flag: complete, values: 0-not complete, 1-automated complete, 2-manuell complete.
COMPLETED_WHEN	DATE	date when milestone status changed to: complete
ACTIVE	NUMBER	status flag: active; a milestone gets active if one of its predecessors gets complete
ACTIVE_WHEN	DATE	date when milestone status changed to: active
MANUAL_COMPLETED_BY	VARCHAR2 (30)	user which changed status of milestone to: complete.
DELIVERY_PERIOD_ID	NUMBER	dimensions. specifies the content of the assigned data packages
DELIVERY_TYPE_ID	NUMBER	
PRODUCTGROUP_ID	NUMBER	
REPORTING_PERIOD_ID	NUMBER	
PROFILE_ID	NUMBER	
PROJ_ID	NUMBER	
TARGET_ID	NUMBER	
REPORT_GROUP_ID	NUMBER	
MAX_VALUE	NUMBER	non-standardised completion degree
CUR_VALUE	NUMBER	
MAX_VALUE2	NUMBER	non-standardised completion degree
CUR_VALUE2	NUMBER	
MAX_VALUE3	NUMBER	non-standardised completion degree
CUR_VALUE3	NUMBER	

attribute	type	description
COUNTRY_ID	NUMBER	country identification
USERNAME	VARCHAR2 (30)	optional: user that works with a data package
DELIVERY_SEQ	NUMBER	version-number of a data package
SUCCESSORS_CREATED	NUMBER	flag used for processing milestone successors
LAST_CHANGED_WHEN	DATE	the last date when this entry has been changed
ACTIVE_FLAG	NUMBER	only the last version of a milestone is relevant
DO_DUE_DATE	DATE	due date of the corresponding data order
PLANNED_DUE_DATE	DATE	expected due date of a milestone
HISTORY_DUE_DATE	DATE	due date calculated as average from the previous three production periods
RULE_ID	NUMBER	rule identification for the calculation of the expected due date
DUEDATE_MANUAL_CHANGED	NUMBER	flag if a user changed the planned due date. values: 1 = yes, 0 = no
DUEDATE_MANUAL_CHANGED_BY	VARCHAR2 (30)	specifies the user that has changes the planned due date.
OLD_CUR_VALUE	NUMBER	used for calculation of the current and max value pair
MS_TXT	VARCHAR2 (100)	description of the milestone
IGNORE	NUMBER	status flag: ignore, value: 1 yes, 0 no
IGNORED_WHEN	DATE	date when milestone status changed to: ignored.
IGNORED_BY	VARCHAR2 (30)	user identification that set ignored the milestone
CREATED_WHEN	DATE	date when the milestone has been created.
LAST_CHANGED_PROG_NAME	VARCHAR2 (5)	name of the background process that changed the status of a milestone
PROG_SECTION	NUMBER	program section of the background process that changed the status of a milestone
OLD	NUMBER	status old specifies that the milestone will not be maintained anymore
OLD_WHEN	NUMBER	date when a milestone becomes the status: old
REMARKS	VARCHAR2 (50)	user remarks
CHECKED	NUMBER	status flag: checked, value: 1 yes, 0 no; specifies whether a user has checked a delayed milestone or not
CHECKED_WHEN	DATE	date when milestone status changed to: checked
CHECKED_BY	VARCHAR2 (30)	specifies who changed the milestone status to: checked

Table: milestone relationships

attribute	type	description
PREDECESSOR_MS_ID	NUMBER	milestone predecessor.
SUCCESSOR_MS_ID	NUMBER	milestone successor
CONN_TYPE	NUMBER	0 = planned relationship. 1 = actual relationship

Appendix D: Original expert assessment questionnaires

Template: Stakeholder report on PCMS

PCMS is GfK's Planning Controlling and Monitoring System – a partly implemented Data Production Management System.

You are asked to contribute to the stakeholder report by completing the two parts of the following questionnaire.

Part 1 asks you to provide **free written text** under **nine headings**. For each heading we set out the aim (what we are trying to find out) together with a number of sub-headings (which may help you in deciding what to say). The sub-headings should only be regarded as illustrative – neither complete nor unalterable. Please feel free to adapt in any way.

Part 2 asks you to provide a combination of **numeric evaluations** and **free written text** under **two headings**, in a standard format.

Part 1

1. **Stakeholder identification**

   Aim: your position and focus in relation to the PCMS

   - Position and summary of responsibilities
   - Involvement in PCMS project
   - Management level of interest in PCMS (e.g. strategic, tactical or operational)

2. **Stakeholder tasks**

   Aim: examples of tasks that you or your staff carry out related to the PCMS

   - List of related tasks
   - Brief description of how the tasks are carried out
   - Examples of how PCMS has helped

3. **Definition and the need for data production management**

   Aim: your view of why computer-aided data production management might be needed in industry

   - What you understand by data production management
   - Whether data production management can be defined in terms of the control of timing, costs and resources
   - Whether data production management can be completely performed by planning, monitoring and controlling data production
   - Business benefit of improved data production management
   - Justification of computer-aided data production management
     (Why is it not advisable to perform data production management manually?)

4. **Requirements of a data production management system**

   Aim: your view of the requirements for a cost-effective data production management system

   (So far identified and from GfK agreed requirements have been the following:
   Showing the status of data packages throughout the workflow. Providing quality means to avoid production errors and to obtain an optimum of data packages scheduled within the allotted time. Overcoming data aggregations and segmentations. Coping with unstable data identifiers as data packages change their identification keys during production. Handling the frequent deviations at run-time. Using exception reporting for management information reduction. Using the periodic repetition for automating the planning. Concentrating on progress monitoring rather than direct corrections in production.)

   - What you think are the main requirements (not more than about ten)
   - Whether PCMS meets those requirements
     o   in today's incomplete implementation
     o   when it is completely implemented
   - Whether data production management should be automated

5. "Loosely coupled" data production management (the design concept adopted for PCMS)

Aim: your assessment of this design decision

- Whether GfK needed an improved data production management system and to what extend
- Whether and to what extend off-the-shelf software (e.g. production planning systems or workflow management systems) could have been used
- Alternative techniques that might be relevant for data production management
- Whether a loosely coupled approach is preferable in GfK to closely coupled or other approaches
  - o *Loosely coupled*: the data production system (DPS) and the data production management system (DPMS) are independent of each other, except for periodic enquiries by the DPMS of production state.
  - o *Closely coupled*: The DPS and DPMS run together, in continual communication.
- Whether the loosely coupled approach is sufficiently scalable and flexible to meet future requirements

6. Data production management with and without PCMS

Aim: your assessment of the change resulting from the introduction of PCMS and of future needs

- How previous possibilities of gathering and storing management information be compared to PCMS in terms of completeness, accessibility, querying possibilities, reliability and maintenance
- International production overviews: how you have done them in the past, how you do them today, what you need for the future
- Key performance indicators: what you have had in the past, what you have today, what you need for the future
- Management information gathering: how you have done it in the past, how you do it today, what you need for the future
- Data production management tasks in GfK: which have been automated in the past, which are automated today, and which should be automated in the future

7. Effectiveness of PCMS

Aim: whether the present and anticipated functions of PCMS give you what you need and, if not, how they might be done better

- Production planning
- View of complete report cycle
- Finding production errors
- Overview of production progress
- Efficiency of production process
- Productivity of production process
- Transparency of production process
- Reduction of waiting times in production
- Adherence to delivery dates
- Planning volume of production
- Planning new reports
- Whether you see limits for PCMS

8. Possible major enhancements in future

Aim: whether you have ideas for major advances in scope in future

- Human resource planning
- Cost management
- Increased customer satisfaction
- Other

9. Overall evaluation

Aim: your honest assessment of life with PCMS

- How much your ability to do your job has been improved or reduced
- Strengths: positive aspects of PCMS
- Weaknesses: negative aspects of PCMS
- Opportunities: chances for the future with PCMS
- Threats: risks for the future with PCMS

Part 2

1. Evaluation of today's implementation of PCMS

Aim: your assessment of the present incomplete implementation in greater detail

Rating scale: {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}

Property	Rating and comment
Example property	4
Reasons and proposals for improvements / comment	WHY you think improvement of PCMS is necessary; if necessary WHAT is needed to improve the situation; any other comments
User-friendliness of PCMS user interfaces	
Reasons and proposals for improvements / comment	
Completeness of production overviews	
reasons and proposals for improvements / comment	
Appropriateness of key performance indicators	
reasons and proposals for improvements / comment	
Production intensity diagram	
reasons and proposals for improvements / comment	
Delay and gain diagram	
reasons and proposals for improvements / comment	
Completeness of key performance indicators	
reasons and proposals for improvements / comment	
Problem identification possibilities	
reasons and proposals for improvements / comment	
Identification of open data potential	
reasons and proposals for improvements / comment	
Transparency of past production	
reasons and proposals for improvements / comment	
Transparency of current production	
reasons and proposals for improvements / comment	

Transparency of future production	
reasons and proposals for improvements / comment	
Production planning possibilities	
reasons and proposals for improvements / comment	
Comparison of current and planned production	
reasons and proposals for improvements / comment	
Production monitoring for PCMS	
reasons and proposals for improvements / comment	
Production control possibilities	
reasons and proposals for improvements / comment	
Scalability of PCMS	
reasons and proposals for improvements / comment	
Reliability of PCMS	
reasons and proposals for improvements / comment	

Please add any other properties which you think would complete your evaluation

Property	Rating and comment
Reasons and proposals for improvements / comment	
Reasons and proposals for improvements / comment	
Reasons and proposals for improvements / comment	

2. Long-term expectations of key performance indicators when PCMS is completed

Aim: your assessment of future requirements in greater detail

Rating scale: {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}

Non-monetary key performance indicators

Key performance indicators	Rating and comment
Example key performance indicator	4
reasons why / comment	Reason for your rating, and comment on why you think the key performance indicator is or is not important
Production (throughput) time	
reasons why / comment	
Set-up time	
reasons why / comment	
Transport time	
reasons why / comment	
Waiting time	
reasons why / comment	
Working time	
reasons why / comment	
Shutdown times	
reasons why / comment	
Down times	
reasons why / comment	
Breakdown times	
reasons why / comment	

Delivery reliability

Key performance indicators	Rating and comment
Delivery reliability	
reasons why / comment	
Supplier reliability	
reasons why / comment	

Process reliability	
reasons why / comment	
Product reliability	
reasons why / comment	

Other key performance indicators

Key performance indicators	Rating and comment
Production system utilisation	
reasons why / comment	
Unused data potential	
reasons why / comment	
Production intensity	
reasons why / comment	
Delays in production	
reasons why / comment	
Productivity	
reasons why / comment	

Monetary key performance indicators: costs

Key performance indicators	Rating and comment
Production costs	
reasons why / comment	

Resource capacity management

Key performance indicators	Rating and comment
Material (data)	
reasons why / comment	
Human resources	
reasons why / comment	

Machines (servers)	
reasons why / comment	

Transparency of production

Key performance indicators	Rating and comment
Overview of production process	
reasons why / comment	
Overview of past production content	
reasons why / comment	
Overview of current production content	
reasons why / comment	
Overview of future production content	
reasons why / comment	

Please add any other key performance indicators which you think would complete your evaluation

Key performance indicators	Rating and comment
reasons why / comment:	
reasons why / comment:	
reasons why / comment:	

GfK Marketing Services
Production & System Development

GfK Marketing Services GmbH & Co. KG · Nordwestring 101 · D-90319 Nürnberg

Frau
Anja Schanzenberger

Date
November 14th, 2005

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Stakeholder Report PCMS

Dear Anja,

as requested, please find my comments on the PCMS project status. They largely follow the questionnaire that you provided to us.

My best wishes for the completion of you Ph.D. thesis.

Kind regards,

Thomas Kirsche

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Commercial register
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Q 1-1 Stakeholder identification

- Dr. Thomas Kirsche, Division Manager
- Responsible for System Development I and strategic data production issues in GfK's Retail & Technology business unit.
- Initiator of the PCMS project.

Q 1-2 Stakeholder tasks (PCMS)

- PCMS product management.
- Maintenance and further development of PCMS software.

Q1-3 Definition and the need for data production management

- Data production management is the "art" of sequencing and interleaving a number of batch jobs that produce outputs needed by other batch jobs. The batch jobs add value to data by aggregation and mixing information from different sources.
- In the GfK market reports environment, the data itself can be replaced equivalently by alternate source without hampering the overall report quality but the report availability deadline. Data production management at GfK aims to have reports with a defined quality available as fast as possible with a economic use of data sources.

Q1-4 Requirements of a data production management system

- Main requirements
  - Provide overview on production progress with respect to timing and completion.
  - Exception management and reporting for deviations.
  - Must be able to cope with large number of states (milestones).
  - Must be able to use plan templates in order to create automatically plan instances for every production period.
  - Lean tool for making quick decisions.
- Whether PCMS meets those requirements
  - PCMS has the clear potential to fulfil all requirements as it has a solid and suitable design.
  - In its current state, PCMS cannot cope with very large number of milestones, and takes too much processing power to do reports and state changes.
- Whether data production management should be (fully) automated
  - Clearly neither a requirement nor a vision. PCMS is a helper application for decision support.

Q1-5 "Loosely coupled" data production management (the design concept adopted for PCMS)

- GfK Retail & Technology's production system is constantly extended and adapted to future needs. It is crucial to have the option to advance the parts of the production system independently. A loose coupling of the PCMS layer on top of an existing Job Execution Environment was the right system architecture.

Q1-6 Data production management with and without PCMS

- GfK always had clear deadlines plans but they have been very coarse. While PCMS now splits the production workflow in 11 steps, GfK MS used to have only 3. Also, while PCMS milestones are now for every product group, retailer, and the like, the old GfK milestones were at a very high level.
- Apart form the plan, there was no real overview on the actual production progress. Rather, department managers had a "feeling" on the status and were acting on the basis of incidents.
- The time/status relationship was never monitored comprehensively but on the basis of incidents. PCMS draws a comprehensive picture.

Q1-7 Effectiveness of PCMS

- PCMS is a very good first step. For the first time, we have a tool covering the production workflow from A-Z. It has made the workflow progress transparent and shows dependencies between production steps. PCMS has the potential to predict future bottlenecks before they actually happen.
- With the current version of PCMS, we are a little bit lost in the vast data pool of milestones which makes it hard to scrutinize for the real causes of problems.

Q1-8 Possible major enhancements in future

- More support for What-if analysis, e.g. how would the deadlines be affected if we add this product group with 50 retailers.
- Ease of use handling, switching from a data-centric GUI to an exception-centric user interaction.

Q1-9 Overall evaluation

- Strengths: More overview than ever before, solid design to cover thousands of milestones. Architecture well suited to create milestone instances form checkpoint templates which support periodic production.
- Weaknesses: Performance, GUI.

- Opportunities: Very good starting point for further versions that go more for the Planning and Controlling of PCMS. The basis is now there like a raw gemstone that has now to be grinded.
- Threads: ./.

Part 2

1. Evaluation of today's implementation of PCMS

Aim: your assessment of the present incomplete implementation in greater detail

Rating scale: {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}

Property	Rating and comment
Example property	4
Reasons and proposals for improvements / comment	WHY you think improvement of PCMS is necessary; if necessary WHAT is needed to improve the situation; any other comments
User-friendliness of PCMS user interfaces	1
Reasons and proposals for improvements / comment	Data-centric approach should be replaced by problem-centric presentation. Navigation between modules should be improved.
Completeness of production overviews	5
reasons and proposals for improvements / comment	(2 checkpoints not implemented yet.)
Appropriateness of key performance indicators	3

reasons and proposals for improvements / comment	Meaningful enough, but presentation could be improved.
Production intensity diagram	4
reasons and proposals for improvements / comment	Saves a lot of time to produce this important document.
Delay and gain diagram	1
reasons and proposals for improvements / comment	Should have been useful to determine critical path and open capacities. Not as useful as I thought when I designed it.
Completeness of key performance indicators	4
reasons and proposals for improvements / comment	Ok.
Problem identification possibilities	1
reasons and proposals for improvements / comment	Hard to navigate through tons of data, lost in milestone space.
Identification of open data potential	n/a
reasons and proposals for improvements / comment	(never tried)
Transparency of past production	2
reasons and proposals for improvements / comment	Good for the overview part, could be improved for the explanation part.

Transparency of current production	2
reasons and proposals for improvements / comment	see above

Transparency of future production	0
reasons and proposals for improvements / comment	forecasting is limited to the next milestones, due to complexity of links
Production planning possibilities	2
reasons and proposals for improvements / comment	Good for computing new deadlines. I don't know how to use PCMS for my "What-if" questions.
Comparison of current and planned production	3
reasons and proposals for improvements / comment	Based on previous production schedules, the new deadlines are computed.
Production monitoring for PCMS	4
reasons and proposals for improvements / comment	good overview in production progress reports
Production control possibilities	n/a
reasons and proposals for improvements / comment	was not the objective for the current version

Scalability of PCMS	1
reasons and proposals for improvements / comment	Current performance problems don't suggest are wide roll-out of the systems. The architecture should be able to scale up, though.
Reliability of PCMS	3
reasons and proposals for improvements / comment	Stable reports even under unmonitored conditions.

2. Long-term expectations of key performance indicators when PCMS is completed

Aim: your assessment of future requirements in greater detail

Rating scale: {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}

Non-monetary key performance indicators

Key performance indicators	Rating and comment
Example key performance indicator	4
reasons why / comment	Reason for your rating, and comment on why you think the key performance indicator is or is not important
Production (throughput) time	0
reasons why / comment	Overall throughput should not be much affected by PCMS, as the controlling part of PCMS would help to overcome current processing limitations.
Set-up time	4
reasons why / comment	
Transport time	n/a

reasons why / comment	
Waiting time	4
reasons why / comment	
Working time	4
reasons why / comment	
Shutdown times	0
reasons why / comment	
Down times	2
reasons why / comment	
Breakdown times	2
reasons why / comment	

Delivery reliability

Key performance indicators	Rating and comment
Delivery reliability	4
reasons why / comment	PCMS reports will help to identify bottlenecks earlier than today. If speed-up or rearrangements of process steps are possible with this knowledge, deliverables will become more reliable.
Supplier reliability	0
reasons why / comment	PCMS reports don't have a direct impact on reliability of retailers.

Process reliability	3
reasons why / comment	As far as timing is concerned.
Product reliability	3
reasons why / comment	As far as timing is concerned.

Other key performance indicators

Key performance indicators	Rating and comment
Production system utilisation	0
reasons why / comment	Usage of production system is enforced with and without PCMS.
Unused data potential	3
reasons why / comment	PCMS will provide respective reports on unused data. As data volume should not be very significant, absolute impact will be little.
Production intensity	4
reasons why / comment	Usage of production system is enforced with and without PCMS.
Delays in production	4
reasons why / comment	Should be far less, as bottlenecks are identified earlier than today
Productivity	1
reasons why / comment	PCMS creates only a theoretical potential for producing more output in the same time.

Monetary key performance indicators: costs

Key performance indicators	Rating and comment

Production costs	0
reasons why / comment	PCMS is about production quality, not about costs. (PCMS development costs are not considered.)
Turnover	1
reasons why / comment	With more reliable deliverables and prediction of problems, PCMS will help building more trust to customers and even generate moderate increase of turnover.

Resource capacity management

Key performance indicators	Rating and comment
Material (data)	0
reasons why / comment	PCMS is about production quality, not about data volume.
Human resources	0
reasons why / comment	PCMS is about production quality, not about costs/human resources.

Machines (servers)	3
reasons why / comment	PCMS production intensity reports have the potential to tell about low hardware usage. Must find ways to apply these knowledge in every day production.

Transparency of production

Key performance indicators	Rating and comment
Overview of production process	5
reasons why / comment	PCMS will provide an excellent overview on process steps, timings and milestones.

Overview of past production content	5
reasons why / comment	It should be possible to create the same overviews for current and past production cycles.
Overview of current production content	5
reasons why / comment	It should be possible to create the same overviews for current and past production cycles.
Overview of future production content	2
reasons why / comment	Prediction possibilities are limited to within the same production cycle.

Stakeholder report on PCMS from Hans Feder

PCMS is GfK's Planning Controlling and Monitoring System – a partly implemented Data Production Management System.

You are asked to contribute to the stakeholder report by completing the two parts of the following questionnaire.

Part 1 asks you to provide **free written text** under **nine headings**. For each heading we set out the aim (what we are trying to find out) together with a number of sub-headings (which may help you in deciding what to say). The sub-headings should only be regarded as illustrative – neither complete nor unalterable. Please feel free to adapt in any way.

Part 2 asks you to provide a combination of **numeric evaluations** and **free written text** under **two headings**, in a standard format.

Part 1

1. Stakeholder identification

In the position of a Division Manager, I am responsible for Data Processing of Retail Tracking Data within Marketing Services. This comprises the processing of incoming retail data to the delivery of these data to our clients. Planning and observation at all production cycles with the aim to meet the timelines for delivery as agreed upon with our clients is a substantial task of production.

I participated in this project as I attended discussions about issues of procedure. In a couple of talks with Mrs. Anja Schanzenberger the production process was described and reasonable checkpoints were found. A first active application of PCMS was limited to some set up measures.

The benefit of PCMS for production lies above all in the planning of complex procedures as well as in the control of all tasks involved in the process.

2. Stakeholder tasks

In order to keep the fixed timelines for delivery, due dates are fixed together with all units involved in production. At each step of production, a separate timeline needs to be defined to meet the target. In the end the production process is supported by due dates. Checking these dates (target vs. performance) is effected by audit and costly at present. The findings go into divers reports, e.g. Gantt reports.

Considering the functionality of PCMS under these aspects, these ideas recur. PCMS reflects procedures through pre-defined milestones and provides the possibility of storing planned dates. A scrolling option for consecutive tasks in PCMS allows relatively easy handling of the schedule. Since delivery dates are agreed upon very individually with each client, it is possible to enter fixed dates.

Although PCMS already offers monitoring functions, these can be properly applied only after all stages of the process are implemented in PCMS, which is not the case at present.

3. Definition and the need for data production management

Data production management is, like any other production management, more or less complex according to the product to be manufactured. Complexity is a consequence of the co-ordination of all contributing processes which require the negotiation of dates and need to be controlled. The participation of third parties in the process (e.g. data delivery from retail) leads to further complexity. The more complex the production process, the more necessary it will become to manage it through a computer-based system. For necessary controlling procedures, a data production management system is a suitable tool, especially for checking the time period necessary for a single step of production. Thus, we consider planning, monitoring and controlling of the process as main tasks of a data production management system.

Given that fixed targets become more and more exacting, planning and monitoring are growing of importance.

Thus traditional tools for planning and control are neither suitable nor applicable any longer. At this point at the latest a computer-based management system should be used. A special benefit of the data production management comes from the fact that process information is already available in database systems.

4. Requirements of a data production management system

Concerning production, the following features of a data production management system can be noted:
⇒ Planning of production dates for each process unit.
⇒ Individual overviews (Gantt-Reports) for the checking of steps against planned dates (target / performance)
⇒ Visualising of the interdependence of single processes
⇒ Compilation of exceptional reports at date issues
⇒ Access to date overviews (target / performance) on different levels
⇒ User-friendly surface for an effective application of the system

In the PCMS version which is currently available, planning components are far developed and ready for application. Besides analyses which can be used at present, more variations resp. more options for individual design are expected. The handling of PCMS, and especially its selecting option, however is not sufficiently convenient at present.

5. "Loosely coupled" data production management (the design concept adopted for PCMS)

It was absolutely necessary and desired to introduce a Data Production Management System together with the implementation of a new Data Production System.

Due to the fact that PCMS is still not used for production, the question whether „Loosely coupled" or „Closely Coupled" for PCMS cannot clearly answered. In view to production, a real-time information is preferable of course, which would make a Closely coupled-Adoption more attractive, insofar as this is possible with regard to performance.
If a „Loosely coupled" adoption of the system is unavoidable, it becomes necessary to define checks of the production system closer to real-time.

6. Data production management with and without PCMS

As PCMS is not productive today, a comparison can only be made on a theoretical basis. No doubt, however, that PCMS information will be available in a depth of detail not possible up to now. Due to the partly manual audit of target and performance dates of the production process, today it is only possible to produce rough analyses.

Especially international overviews can only be realized at the cost of high communicational efforts because a great deal of the information has to be collected in conventional channels.

The information collected in that way serves as a basis to international date overviews and form a plan schedule for an international process management. Here, issues such as operating performance or the setup of timeframes for system updates come to the fore.

7. Effectiveness of PCMS

An evaluation of the range of functions in the test environment is only marginal:

- Production planning: Sufficient range of functions.
- View of complete report cycle: Not possible because of missing Milestones, but urgently desired.
- Finding production errors: Only indirectly visible but sufficient in the context. A concrete error search option seems desirable but cannot be realised at the moment.
- Overview of production progress: Is necessary and must form a substantial part of DPMS in view of production.
- Adherence to delivery dates: Owing to the fact that deliveries are often effected from various sources, this item plays an important role in the assessment of the delivery in total.
- Planning volume of production: For planning notably technical resources.

The following items are desirable for special analyses in PCMS:

- Efficiency of production process
- Productivity of production process

8. Possible major enhancements in future

The aim is to manage all plan data in PCMS if possible in order to get an idea of resources required in the future. These can be personal or technical resources and as well computing capacities.
The forecast of plan data should be enhanced to allow that also "marginal planning" can take place, such as system upgrades on the basis of plan data for production timelines.

9. Overall evaluation

PCMS could not be applied in production unfortunately because essential milestones could not be implemented so far. Tests of the software were therefore limited to the setup, notably the management of target dates for milestones already implemented.

It must be marked as positive that all performance data are received directly from the production system. Thus the communicative effort which is existing today will be spared. The first impression that analyses made was very good and it may be expected that the improvement capacity is very high.

The instruction for use however has to be considered negative in the present version as the system appears extremely complex for users. Especially selection options and navigation within the system are not made clear enough to the user.

Part 2

1. Evaluation of today's implementation of PCMS

Aim: your assessment of the present incomplete implementation in greater detail

Rating scale: {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}

Property	Rating and comment
Example property	4
Reasons and proposals for improvements / comment	WHY you think improvement of PCMS is necessary; if necessary WHAT is needed to improve the situation; any other comments
User-friendliness of PCMS user interfaces	-3
Reasons and proposals for improvements / comment	
Completeness of production overviews	-2
reasons and proposals for improvements / comment	Relevant overviews are still missing. Compact international overviews are essentially important. .
Appropriateness of key performance indicators	2
reasons and proposals for improvements / comment	
Production intensity diagram	3
reasons and proposals for improvements / comment	
Delay and gain diagram	3
reasons and proposals for improvements / comment	
Completeness of key performance indicators	3
reasons and proposals for improvements / comment	
Problem identification possibilities	-2
reasons and proposals for improvements / comment	It is not possible to conclude a problem from a delay.
Identification of open data potential	3
reasons and proposals for improvements / comment	
Transparency of past production	3
reasons and proposals for improvements / comment	
Transparency of current production	3
reasons and proposals for improvements / comment	

Transparency of future production	3
reasons and proposals for improvements / comment	
Production planning possibilities	4
reasons and proposals for improvements / comment	
Comparison of current and planned production	2
reasons and proposals for improvements / comment	
Production monitoring for PCMS	-2
reasons and proposals for improvements / comment	Because of missing Milestones not all checkpoints available.
Production control possibilities	2
reasons and proposals for improvements / comment	In terms of time management.
Scalability of PCMS	3
reasons and proposals for improvements / comment	
Reliability of PCMS	-
reasons and proposals for improvements / comment	A concrete statement can only be made in a productive environment..

Please add any other properties which you think would complete your evaluation

Property	Rating and comment
Reasons and proposals for improvements / comment	
Reasons and proposals for improvements / comment	
Reasons and proposals for improvements / comment	

2. **Long-term expectations of key performance indicators when PCMS is completed**

   Aim: your assessment of future requirements in greater detail

   Rating scale: {-5 strong negative, -4, -3, -2, -1, 0 no change, 1, 2, 3, 4, 5 strong positive}

   Non-monetary key performance indicators

Key performance indicators	Rating and comment
Example key performance indicator	4
reasons why / comment	Reason for your rating, and comment on why you think the key performance indicator is or is not important
Production (throughput) time	5
reasons why / comment	
Set-up time	-4
reasons why / comment	
Transport time	0
reasons why / comment	
Waiting time	4
reasons why / comment	
Working time	3
reasons why / comment	
Shutdown times	-4
reasons why / comment	
Down times	4
reasons why / comment	
Breakdown times	4
reasons why / comment	

Delivery reliability

Key performance indicators	Rating and comment
Supplier reliability	4
reasons why / comment	

Process reliability	4
reasons why / comment	
Product reliability	5
reasons why / comment	

Other key performance indicators

Key performance indicators	Rating and comment
Production system utilisation	4
reasons why / comment	
Unused data potential	3
reasons why / comment	
Production intensity	5
reasons why / comment	
Delays in production	5
reasons why / comment	
Productivity	5
reasons why / comment	

Monetary key performance indicators: costs

Key performance indicators	Rating and comment
Production costs	3
reasons why / comment	

Resource capacity management

Key performance indicators	Rating and comment
Material (data)	2
reasons why / comment	
Human resources	3
reasons why / comment	

Machines (servers)	4
reasons why / comment	

Transparency of production

Key performance indicators	Rating and comment
Overview of production process	5
reasons why / comment	
Overview of past production content	5
reasons why / comment	
Overview of current production content	5
reasons why / comment	
Overview of future production content	5
reasons why / comment	

Please add any other key performance indicators which you think would complete your evaluation

Key performance indicators	Rating and comment
reasons why / comment:	
reasons why / comment:	
reasons why / comment:	

Appendix E: Discussion of further scenarios

The scenarios described in this appendix have been evaluated during this research project in addition to the scenarios exemplarily described in section 7.5. They contribute consequently to the presented evaluation results. The evaluation results of the loosely coupled approach (see section 5.2.3) are shown by presenting its functional benefits on the operational (see section E.1) and on the strategic and tactical level (see section E.2). Each scenario is evaluated by showing operational consequences, the chain of business effects and weighted tangible and intangible benefits.

E.1   Operational level

E.1.1   The whole story: Example of one production cycle

This scenario shows how complete production cycles can be visualised and how effective such production overviews can be. The result is, although the visualisation of net plans is still complex, the benefits, such as forwards and backwards tracking of the data flow, are appealing in PDP.

I.   Scenario

A complete production cycle: The whole production cycle of PDP can be visualised when using the loosely coupled approach. This scenario is achievable by taking advantage of the affinity to PM and the concepts of Pert diagrams. The predecessor and successor relationships between the milestones are the only information that is necessary for enabling this overview as demonstrated in section 6.3.4.1. Storing this data flow in database tables allows querying. The aim of these overviews are to gain more transparency in production. The example presented in figure E.1 shows one of the production cycles from checkpoint CP0 to checkpoint CP7. The example has been queried with the Milestone-Administration tool of the prototype. The scenario described in this example demonstrates forwards tracking of a data package in a specific period, that represents in this case the retailer 'TELEKOMMUNIKATION GATZKE' and shows in which end-reports (in checkpoint CP7) the data of this retailer are used. Of course, backwards tracking is also possible when following the data flow in the reverse direction. Tracking the complete data flow adequately requires therefore always a starting point (e.g. a specific milestone or a group of milestones) and a direction (forwards or backwards). The example provided in figure E.1 is

only a very small example and demonstrates the need for sophisticated visualisation tools as net plans usually tend to quickly become complex.

Interpretation and particularities in the chosen example: One milestone at checkpoint CP2 and two milestones at checkpoint CP5 have no successors. At checkpoint CP2 this means that the input/output pool has been filled with the data that the milestone specifies, but these data are not used in any end-report. This can point to open data potential as for example the product-group '15692:MOBILEPHONE ACCESSORY' can be sold as a new panel if there is an interest for customers. This can also point to production errors, such as the data package has been simply not considered. Production operators are now able to analyse these cases accordingly. The reason for a lack of successors in checkpoint CP5 seems to be a different case. When tracking the predecessors of these milestones down to checkpoint CP2, the following can be found: The predecessors at checkpoint CP2 are all completed. Neither are the milestones in this chain of checkpoint CP3 and CP4 completed, nor are both milestones at CP5. The reason in this case can be that these data packages have been replaced by the first two milestones at checkpoint CP5. The reason for this replacement could be that both milestones at CP5 and its related predecessors up to CP3 are old data packages. Production operators could reduce complexity in production if they would deactivate the master data that are used for producing these old data packages. Their action is in this case to clean up production. Those actions increase in turn the up-to-dateness and the production overview. Without the overview of the whole production cycle these analysis types are not possible.

The example demonstrates that visualising predecessor and successor relationships advances PDPM from simple state checking of unrelated data packages to sophisticated time management. The relationships of the milestones can be used for all forward and backward calculations in relation to the timing in PDP.

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
0	TELEKOMMUNIKATION GATZKE - 0510(M)	07.11.2005 23:59:00	02.11.2005 23:33:08

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
1	TELEKOMMUNIKATION GATZKE - 0510(M)	09.11.2005 23:59:00	04.11.2005 03:33:55

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
2	TELEKOMMUNIKATION GATZKE - 0510(M)-15647:CELLULAR RADIO PHONES	16.11.2005 10:0000	04.11.2005 03:3506
2	TELEKOMMUNIKATION GATZKE - 0510(M)-15690:MOBILEPHONETARIFFS	16.11.2005 10:0000	04.11.2005 03:35:06
2	TELEKOMMUNIKATION GATZKE - 0510(M)-15692:MOBILEPHONE ACCESSORY	09.11.2005 23:5925	04.11.2005 03:3506

no successor

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
3	[14927] DE- PROD IT 1-mon Standard-Oct05	15.12.2005 10:47:00	17.11.2005 17:58:55
3	[23762] DE- PROD IT 1-mon Tariffs without-Oct05	16.11.2005 14:5900	- - -
3	23763] DE- PROD IT 1-mon Tariffs only-Oct05	16.11.2005 14:5900	- - -

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
4	[14927] DE- PROD IT 1-mon Standard-Oct05	16.12.2005 10:4700	18.11.2005 11:27:12
4	[23762] DE- PROD IT 1-mon Tariffs without-Oct05	17.11.2005 14:5900	- - -
4	[23763] DE- PROD IT 1-mon Tariffs only-Oct05	17.11.2005 14:5900	- - -

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
5	15647:CELLULAR RADIO PHONES-[3810]-DE- TEL Mobile Phones 1m-Oct05	20.12.2005 10:4700	18.11.2005 13:0828
5	15647:CELLULAR RADIO PHONES-[6225]-DE- TEL Mobile Phones 1m-Oct05	20.12.2005 10:4700	22.11.2005 18:0313
5	15690:MOBILEPHONETARIFFS-[23419]-DE-TEL Mobile Phone Tariffs 1m-Oct05	17.11.2005 18:58:00	- - -
5	15690:MOBILEPHONETARIFFS-[23422]-DE-TEL Mobile Phone Tariffs 1m(o2+T-m)-Oct05	17.11.2005 18:5800	- - -

no successor

CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
6	15647:CELLULAR RADIO PHONES-[3810]-DE- TEL Mobile Phones 1m-Oct05	24.11.2005	21.11.2005 14:05:44
6	15647:CELLULAR RADIO PHONES-[6225]-DE- TEL Mobile Phones 1m-Oct05	24.11.2005	23.11.2005 13:20:38

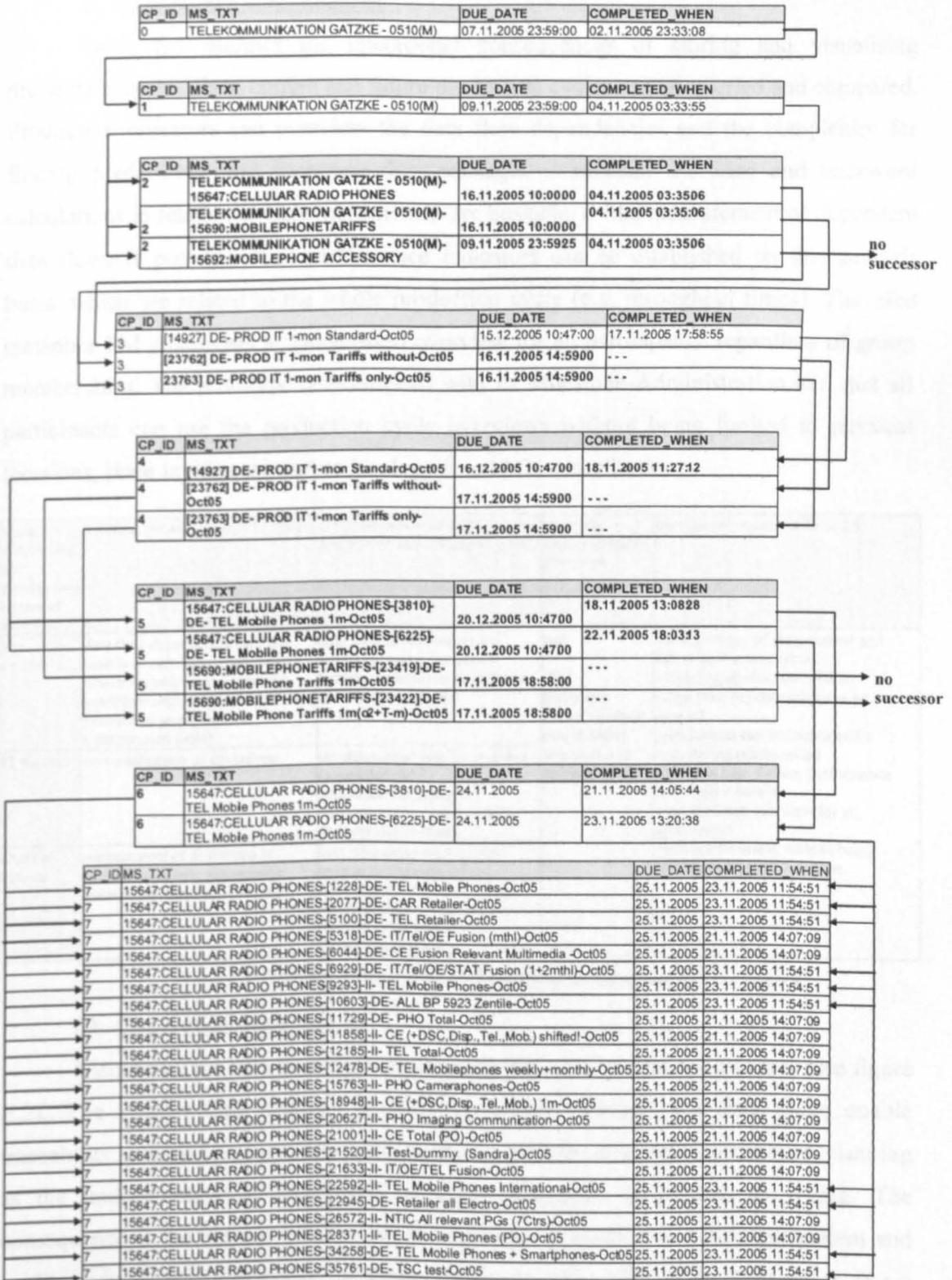| CP_ID	MS_TXT	DUE_DATE	COMPLETED_WHEN
7	15647:CELLULAR RADIO PHONES-[1228]-DE- TEL Mobile Phones-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[2077]-DE- CAR Retailer-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[5100]-DE- TEL Retailer-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[5318]-DE- IT/Tel/OE Fusion (mthl)-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[6044]-DE- CE Fusion Relevant Multimedia -Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[6929]-DE- IT/Tel/OE/STAT Fusion (1+2mthl)-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[9293]-II- TEL Mobile Phones-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[10603]-DE- ALL BP 5923 Zentile-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[11729]-DE- PHO Total-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[11858]-II- CE (+DSC,Disp.,Tel.,Mob.) shifted!-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[12185]-II- TEL Total-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[12478]-DE- TEL Mobilephones weekly+monthly-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[15763]-II- PHO Cameraphones-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[18948]-II- CE (+DSC,Disp.,Tel.,Mob.) 1m-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[20627]-II- PHO Imaging Communication-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[21001]-II- CE Total (PO)-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[21520]-II- Test-Dummy (Sandra)-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[21633]-II- IT/OE/TEL Fusion-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[22592]-II- TEL Mobile Phones International-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[22945]-DE- Retailer all Electro-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[26572]-II- NTIC All relevant PGs (7Ctrs)-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[28371]-II- TEL Mobile Phones (PO)-Oct05	25.11.2005	21.11.2005 14:07:09
7	15647:CELLULAR RADIO PHONES-[34258]-DE- TEL Mobile Phones + Smartphones-Oct05	25.11.2005	23.11.2005 11:54:51
7	15647:CELLULAR RADIO PHONES-[35761]-DE- TSC test-Oct05	25.11.2005	23.11.2005 11:54:51

Figure E.1: Example of a complete production cycle queried with the prototype

II. Operational consequences

Table E.1 outlines the operational consequences of storing and visualising production cycles. Past, current and future production cycles can be queried and compared. Production operators can overview the data flow dependencies and the complexity for finding predecessor and successor data packages is reduced. Forward and backward calculations in relation to time management are possible, as the measurement of dependent data flows is possible. Key performance indicators can be established on this analysis basis, which are related to the whole production cycle (e.g. throughput times). The used metaphor PM guarantees a standardised overview for all participants, regardless of group memberships. The prototype demonstrated with its Milestone-Administration tool that all participants can use the production cycle overviews without being limited to physical locations, since in this case web technology is used for visualisation.

scenario: displaying the production cycles of reports	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
Pre-conditions	data flow dependencies are not visible or only visualised in tools which are only used in specific workflow segments (i.e. tools like production steps, logs, or extrapolation tools)	data flow dependencies are available; quick navigation between milestones on different checkpoints possible	yes GUI: Milestone Administration (see detailed description in section6.3.4.1)	- transparency of past, current and future production cycles - reducing product complexity - data flow dependencies can be queried - production can be measured by considering relationships - analysis base for key performance indicators available - standardized overview for all participants - links participants without being limited to physical locations
IT support	no visualisation of deviations	deviation overview for free due to automation; deviations visualised in milestones' planned due dates and completion dates		
Derived actions	management of deviations is complex (i.e. only manageable because staff has knowledge);	data flow dependencies are queried as the need arises; most important deviations are investigated and if possible avoided in subsequent production periods		

Table E.1: Operational consequences of displaying the production cycles of reports

III. Chain of business effects

Visualising the data flow improves the production overview for all users (see figure E.2). The relationships between milestones, which represent the data flow, enable traceability. Improved traceability leads to the opportunity to enhance production planning as the understanding of workflows identifies potentials in relation to timing. The consequence is the process quality can be improved in relation to time management and quality reductions can therefore be better prevented. The effect in the long run is that a company that owns a PDP, which is aware of its data dependencies in each production cycle, is highly competitive compared to competitors without such overviews. The reasons

are that such a company is able to derive necessary actions faster and that these actions can be well-chosen due to the knowledge of the data flows.
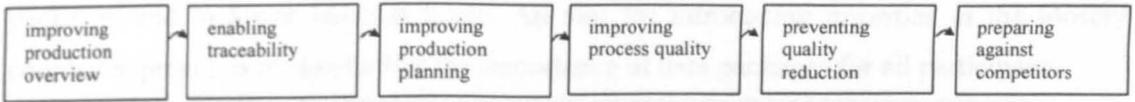
improving production overview		enabling traceability		improving production planning		improving process quality		preventing quality reduction		preparing against competitors

Figure E.2: Economic effects of displaying the production cycles of reports

IV. Evaluation result

The strengths of this scenario are its improvements in relation to a production overview and that production traceability is supported (see table E.2). Both issues are thus evaluated as highly relevant. The other issues mentioned are the consequences over time: The improvements in production planning, process quality, prevention of quality reductions and the preparation against competitors are factors that are positively influenced by using this scenario in PDPM. This scenario is implemented in the prototype and tests with the prototype have effectively demonstrated that quick navigation possibilities through the whole international production chain is clearly an added value. The automated creation of this overview saves manpower as production operators need not to spend time on tracking complex data flows in the distributed PDP system's databases.

operational criteria	timing				costs			quality						future-orientation	
benefit	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
displaying the production cycles of reports		+							+	++	++		+	+

Table E.2: Evaluation results for the scenario: Displaying the production cycles of reports

E.1.2 Work lists with priorities

The archetype of the scenario, which is presented in this section, is workflow management. Several commercial representatives entail the use of work lists (Leymann & Roller, 2000, 102-104). Work lists can also be provided when using the loosely coupled approach for supporting PDP users. The usefulness of work lists increases if production priorities are added. A consequence if the prioritisation algorithm is correctly implemented is that the planning of production can be improved.

I. Scenario

The idea: In PDP it is often crucial to divide between important and less important data packages. Important data packages are absolutely necessary for finishing end-reports. For example, in market research some data packages of retailers are necessary to adequately represent the market and to achieve a high coverage. Production operators have

thus a need to easily identify the importance of data packages. If the priority of data packages is known, this information can be used to speed up production for important data packages and to lower reaction times. An aim for introducing priorities in the loosely coupled approach is to standardize the importance of data packages for all participants.

work-list					
checkpoint 1: FFI available					
country: Germany					
priority	No.	milestone text	due date	completed	delayed
A	M1	MEDIA/SATURN-0516 (weekly)	27.04.2005 23:59	no	no
A	M2	GETMOBILE AG-0516 (weekly)	27.04.2005 23:59	no	no
B	M3	JE COMPUTER -0516 (weekly)	29.04.2005 23:59	no	no
C	M4	KOMSA-0516 (weekly)	25.04.2005 16:22	no	yes
C	M5	GRAVIS -0516 (weekly)	25.04.2005 16:22	no	yes
C	M6	BRÜNNNGS+SANDER -0516 (weekly)	27.04.2005 23:59	no	no

Table E.3: Example of a work list with priorities

An example: The example provided in table E.3 shows a work list of milestones at checkpoint CP1 which are ordered by priorities and due dates. Production operators can now decide whether to tread milestones with priority A or to examine first the delays of the milestones M4, M5 with priority C. If a production operator requires a ranking of the most delayed milestones, he can use the milestones' problem list *'ranking for delayed not completed'* introduced in section 6.3.4.3. Operators have the opportunity to schedule milestones with minor priorities to less production critical times and to equalise peak times. This re-scheduling can take successor relationships into account similar to the scenario discussed in section 7.5.4.1. Work lists can be sent automatically to participants via e-mail.

priority	check -point	delivery type	delivery period	product-group	reporting period	project	report profile	client period	client	respon- sible
A	1	MEDIA/SATURN								smith
B	1	GETMOBILE AG								meier
A	1	GETMOBILE AG	0516 (weekly)							meier
B	1	JE COMPUTER								smith
C	1	KOMSA								group1
C	1	GRAVIS								group1
C	1	BRÜNNNGS+ SANDER								group2
A	2			PTV/FLAT screens						smith

Table E.4: Possible table for storing milestone priorities in case of the prototype

Model of the database table for storing priorities: Table E.4 represents a possible table for storing milestone priorities. The priority, the checkpoint and the milestone dimensions are attributes in this table. The table can be modelled in a way that exceptions for choosing priorities are possible. This enables flexibility in relation to differences in specific production periods. For example, the retailer 'GETMOBILE AG' has usually priority B. However, in the calendar week 16 in 2005 this retailer had priority A. If

additionally names of responsible operators or work-group identifiers are stored, then it is possible to display the users own work lists.

II. Operational consequences

scenario: work lists with priorities	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
preconditions	production priorities are often not clear; communication of changes in priorities is insufficient	work lists and priorities are documented	no	- production priorities are clear and quickly communicated between all participants - staff knowledge is documented - new staff members can be integrated easier - important product parts are produced first - ranking can be shown in production overviews
IT support	priorities are often not communicated between participating departments	priorities can be queried for each checkpoint		
derived actions	work lists are manually created and sent to participants	participants plan production according to priorities; e-mails that include the work lists are used		

Table E.5: Operational consequences of work lists with priorities

As summarised in table E.5, the described scenario supports a clear and quick communication of production priorities between all participants. The knowledge about prioritised data packages is documented and new production operators can thus be quicker integrated. Peak-times can be reduced as important data packages are produced first. The ranking of the data packages which are represented in milestones can be used to advance appropriate production overviews.
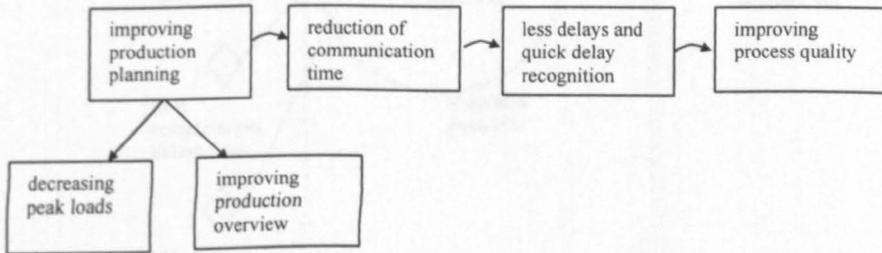
III. Chain of business effects

Figure E.3: Economic effects of work lists with priorities

Work lists with priorities are used to improve production planning as operators are enabled to process important data packages first (see figure E.3). Less critical delays are the consequence. This helps to decrease peak loads. Production overviews can be enriched by additionally showing the priorities. Production operators do not loose sight of important data packages in the wealth of milestones. As priorities are deposited in the PDPM system a reduction of communication time between participants is expected as priorities need not to be orally communicated. This helps quickly to recognise delays in production and equally to reduce delays. The process quality can consequently be improved in relation to time management.

IV. Evaluation result

The scenario to provide work lists with priorities improves substantially production planning and increases process quality (see table E.6). A slight reduction of communication time and delays is the consequence. Peak loads can be slightly reduced. Production overviews enriched with priorities can be presented.

operational criteria	timing				costs			quality					future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
work lists with priorities	com, d	++		+					++		+			

Table E.6: Evaluation results for the scenario: Work lists with priorities

E.1.3   Example for detecting problems in the production chain

In this section a scenario is demonstrated of how production problems in the production chain can be identified by using the loosely coupled concept. This is a representative example for delivering decision support for production operators.
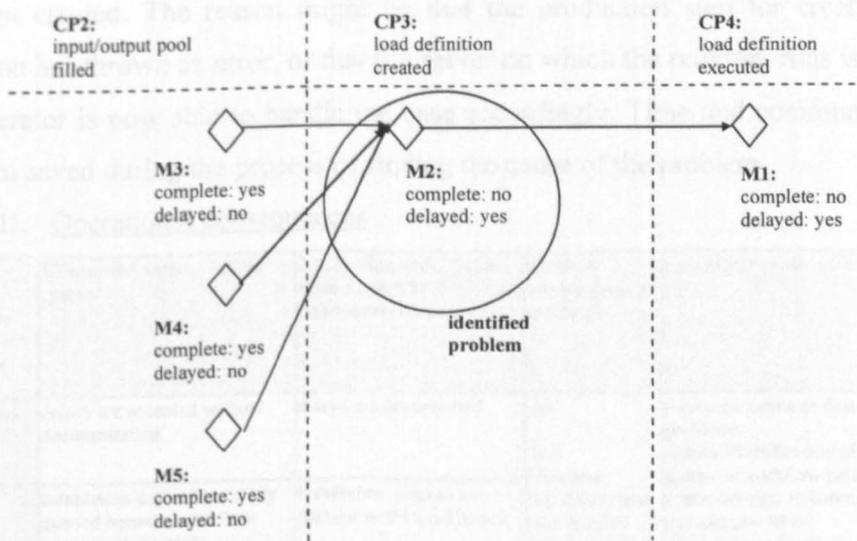

Figure E.4: Example of detecting problems in the production chain

I.   Scenario

The idea: It is essential to enable a quick navigation through the milestone chain to be able to identify the currently produced data packages. Exception reporting is a good concept to find the points of interest. Points of interest, for example, can be milestones which are delayed. As all delays of the whole production are registered in the milestones no important delay can remain undetected. Delayed milestones can especially point to production problems. Although, this is not necessarily a fact, because milestones do not directly show production errors, equally not all delays are crucial incidents. However,

taking into account delayed milestones helps to filter issues for manual investigations.

An example (see figure E.4): Let us assume a production operator checks milestone M1 at checkpoint CP4. This milestone is not completed and is delayed. However, the operator needs urgently the related data packages. Without the PDPM tool he would have to query different logs in the PDP database or to ask responsible operators of former workflow segments to find the wanted data packages, the predecessors, and the last status. With the PDPM tool, the operator is able to navigate within seconds to the predecessor of M1, which is M2. The status of M2 is also incomplete and delayed. The operator knows now that the problem lies not in checkpoint CP4 but already in checkpoint CP3. The operator can then navigate to the predecessors of M2 and he is able to find quickly that M3, M4 and M5 are completely produced and that all three milestones have not been delayed. The operator has identified that the origin of the problem lies in M2. He can now very specifically decide about any actions he might want to take. An action could for example be that the operator queries the PDP database why the load-definition for M2 has not been created. The reason might be that the production step for creating the load-definition has thrown an error, or that the server on which the program runs is a bottleneck. The operator is now able to handle the case accordingly. Time and communication effort had been saved during the process of finding the cause of the problem.

II. Operational consequences

scenario: detecting problems in the production chain	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
preconditions	delays are accepted without documentation	delays are documented	yes GUI: Milestone Administration (see detailed description in section 6.3.4.1)	- documentation of delays and other problems - quick identification of problematic product pieces or workflow parts - time savings: in communication time and consultation time - possibility of analysis available - proactive problem notification possible by sending e-mails
IT support	completion degrees are orally queried between workflow segment participants	completion degrees are queried as the need arises		
derived actions	often re-occurring problems are not adequately known and solved	most important delays are investigated; re-occurring problems are investigated		

Table E.7: Operational consequences of detecting problems in the production chain

As summarised in table E.7, delays are documented in a PDPM system based on the loosely coupled concept. Delays can indirectly point to other production problems. Thus, a quick identification of problematic data packages or workflow parts can be achieved when investigating and analysing delays. As fast navigation and advanced filtering is offered, time savings in communication and consultation time are achievable. Possible are e-mails which proactively notify operators about delays and about problems.

III. Chain of business effects

Quick navigation through the milestone chain and advanced filtering of delayed milestones improves the production overview (see figure E.5). As delays can be identified early, this process saves communication time, waiting time, and time for finding indirect production errors. A reduction of delays helps to prevent penalties. This has in the long run positive effects on the turnover and the production costs in PDP. Early error identification increases the process quality and subsequently prevents quality reductions, and triggers over time an increase of productivity.
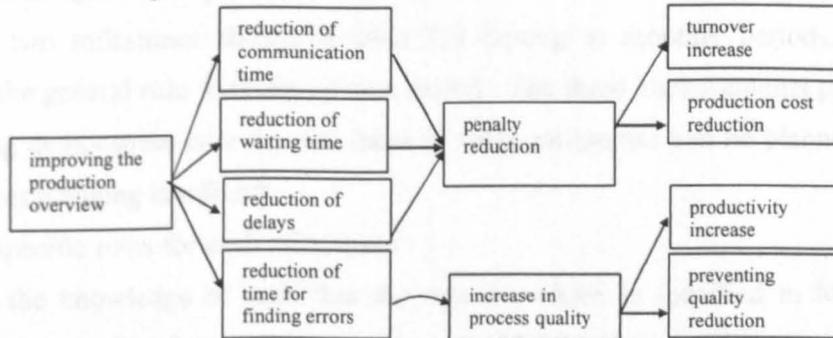

Figure E.5: Economic effects of detecting problems in the production chain

IV. Evaluation result

Early problem detection mainly increases the process quality and prevents quality reductions (see table E.8). Reductions of time in relation to communication, waiting time, delays and time for finding errors are achievable. This increases to a certain extent productivity and definitely prevents penalties. A respectable reduction or saving in penalties slightly affects in the long-run production costs and turnover. The improvement of production overview leads indirectly to an improvement of customer satisfaction, as delays are promptly treated. Altogether this prepares a company against competitors. Tests with the prototype have shown that time reductions are achievable and will especially be relevant for detecting production problems in relation to the international interplay of PDP.

operational criteria	timing				costs			quality						future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
detecting problems in the production chain	com,w, d,e			+	high	low	low		++		+	+	++	+

Table E.8: Evaluation results for the scenario: Detecting problems in the production chain

E.1.4 Due date planning and refinement

The repetitive character of PDP can be used to improve production planning. The scenario presented in this section shows the planning procedure for future production

cycles and gives clues about how due dates of milestones can be improved.

I. Scenario

No.	checkpoint	milestone text	due date	completed
M1	1	DIXONS-0511 (monthly)	06.12.2005 23:59	no
M2	1	GETMOBILE AG-0511 (monthly)	06.12.2005 23:59	no

Table E.9: Example of two milestones planned for the rule '6.th day of next month'

Production planning by using the loosely coupled concept can be crucially advanced. As explained in section 6.3.4.2, due date rules are proposed in this concept to refine the planning. Its strength will be demonstrated with the following examples: Let us assume the two milestones shown in table E.9 belong to monthly periods. They are assigned to the general rule '6.th day of next month'. The three improvements presented in the following demonstrate how the due dates of these milestones can be planned in more detail and thus planning is refined:

- Create specific rules for each milestone:

    Due to the knowledge of staff that the retailer, which is specified in M1, usually delivers data earlier than indicated in the general rule, the specific rule '5.th day of next month at 04:00 o'clock p.m. when DIXONS is the retailer' for M1 could be established. Waiting time in case of M1 can effectively be reduced. M2 is not affected from this new rule and its due date will stay the same.

- Planning known delays in advance:

    If staff knows that the retailer DIXONS delivers two weeks later in December 2005 because the retailer plans a reorganisation of its internal software environment, production operators could specify the rule '19.th day of next month at 04:00 o'clock p.m. when DIXONS is the retailer and the delivery period is December 2005'. This produces an exceptionally planned due date for the December period of milestone M1 and advances planning as production operators of latter workflow segments are informed early.

- Forwards and backwards planning with rules:

    Rules can be extended to enable forwards and backwards planning. This is possible if rules are introduced that relate to predecessor or successor due dates in the milestone chain. A rule for planning forward is: 'checkpoint $CP_{X-1}+2$ days' enables forwards planning, whereas the rule 'checkpoint $CP_{X+1}-2$ days' enables planning backwards. In case of M1 a rule for planning forwards would be 'checkpoint CP_0+2 days'. This means, that the plan is very well adjusted for the individual need in timing of this production data package, because if the predecessors in checkpoint CP0 will be

delayed, it is clear at each point of time how long it will take (e.g. 2 days) to complete M1. Backwards planning will be of more interest in PDP, because usually the delivery date of the end-report is the most important deadline. Respectively, there is a need to plan the timing in production backwards.

II. Operational consequences

The operational consequences of the described scenario are summarised in table E.10. The consequences include that by engaging the loosely coupled approach and rules for the due dates of milestones anticipates that production planning can be automated. Due dates can be calculated for future production cycles in advance. The planned due dates help to estimate the time-demand in PDP. If necessary, each milestone can be individually planned or even more general rules for milestone groups are possible. Former rough and manual planning procedures are replaced by reliable and detailed automated plans. As the standardised plan is visible for all participants, communication times can be reduced. Waiting times can be detected before they take place. Days with heavy production loads can be identified previous to production and thus production critical days can be minimised. Decision support for balancing production is supported.

scenario: due date planning and refinement	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
Pre-conditions	due dates of predecessor/successor production steps not known	due dates of predecessor/successor can be queried	yes	- planning in advance possible - planning in advance enables the estimation of the time need - imprecise, rough planning is replaced by very detailed planning - reduction of communication times between participants - reduction of waiting times - minimising production critical days - standardized overview of the plan for all participants - stress reduction because balanced production is facilitated
IT-support	due dates are only roughly estimated and are not based on calculated values	automated due date calculation in each period; rules can be introduced	GUI: Rule Administration (see detailed description in section 6.3.4.2)	
Derived actions	manual plan creation each period	manual rule creation only once for initialisation; due dates are planned on detailed level on reliable and automated calculations		

Table E.10: Operational consequences of due date planning and refinement

III. Chain of business effects

The described scenario demonstrates that production planning can essentially be improved by the proposed PDPM system (see figure E.6). The automation of the scenario implies a reduction of communication and waiting times, increases thus productivity, and helps to prevent penalty costs. This influences production costs and leads finally to an increase of the turnover. Improving production planning also increases the process quality and thus strengthens the customer retention. If customers are satisfied, this is usually the best preparation against competitors.
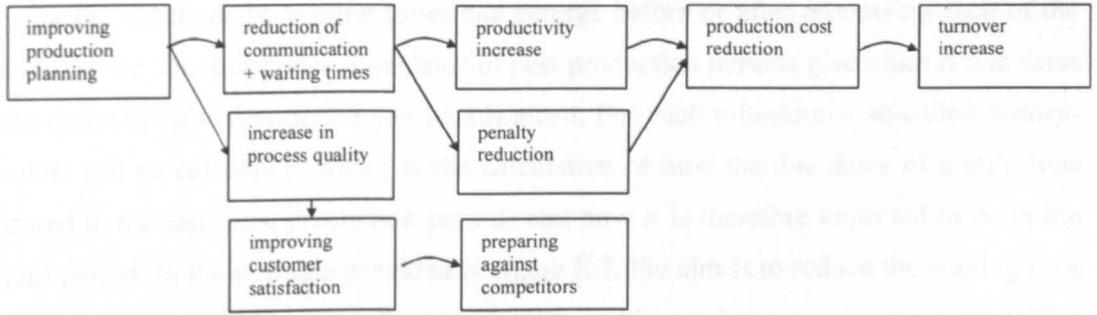
Figure E.6: Economic effects of due date planning and refinement

IV. Evaluation result

The automation of production planning reduces the manual planning effort, sustains the reliability of the production plan and helps to identify future production bottlenecks (see table E.11). Consequently, the described scenario improves to a large extent production planning. Time management can be improved and as a result the productivity will increase. Future penalty payments can be avoided and thus production costs reduced and the turnover moderately increased. Production planning and due date refinement reinforce the process quality and contribute therefore to the improvement of customer satisfaction. A high-quality production process is a good argument for customers to stay and not to change to competitors. The experts experiences with the prototype led to the conclusion that enhancing and automating the planning with rules is comfortable and effective.

operational criteria	timing				costs			quality						future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
due date planning and refinement	com,w	++		++	high	moderate	low		++			+		++

Table E.11: Evaluation results for the scenario: Due date planning and refinement

E.1.5   Reduction of waiting times

The detection of waiting times is desirable in every production type. The reduction of waiting times influences usually the productivity. This section evaluates how satisfactorily waiting times in PDP can be detected and avoided by using the loosely coupled approach.

I.   Scenario

A direct reduction of waiting times is not possible with the loosely coupled approach, because between adjacent checkpoints the completion of more than one production step can be necessary. If various production jobs need to be processed between

the adjacent checkpoints, waiting times can emerge before or after processing each of the jobs. However, the milestones' due dates of past production periods give clues if due dates of the current production period can be advanced. For each milestone a so-called *history-due-date* can be calculated, which is the calculation of how the due dates of a milestone appeared in the last three production periods and how it is therefore expected to be in the current period. In the example provided in figure E.7, the aim is to reduce the waiting time at milestone M4. For this reason, first the due dates of its predecessors are considered. This leads to the insight that milestone M2 has the closest due date to M4. The history-due-date of M2 indicates that production is usually earlier completed than expected. The history-due-date of M4 indicates the same. The result is, waiting time has been detected and can now be reduced by changing the rule for planning the due date accordingly.
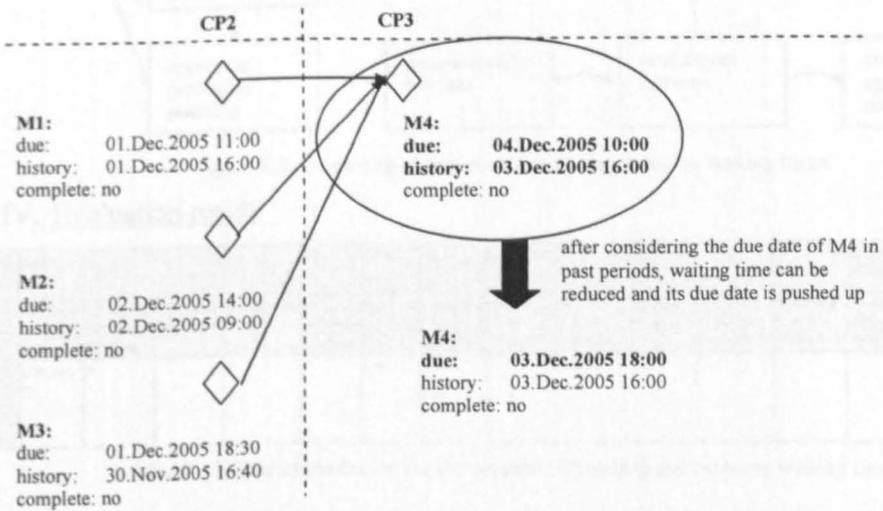

Figure E.7: Example of detecting and reducing waiting times

II. Operational consequences

The consequence of the scenario is that a moderate reduction of waiting times can indirectly be achieved (see table E.12). Participants are enabled to use their work time more efficiently.

scenario: reduction of waiting times	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
pre-conditions	waiting times are unknown	waiting times are monitored	yes GUI: Milestone Administration (see detailed description in section 6.3.4.1)	- reduction of waiting times achievable - savings of human resources can be achieved
derived actions	the most important date is the report delivery date to the customer	waiting times are as much as possible eliminated; due dates at all checkpoints are relevant		

Table E.12: Operational consequences of detecting and reducing waiting times

III. Chain of business effects

The proposed PDPM system delivers not only decision support for the reduction of waiting times, but offers also the possibility for participants to query the adjusted due dates (see figure E.8). This reduces communication and coordination times and improves the future production plans. Waiting time reductions influence throughput times and point thus to penalty savings. This leads to a reduction of production costs and in the long-run to a turnover increase. Improving future production plans triggers an increase in process quality and a productivity increase. The companies that effectively carry out PDPM in relation to waiting time reductions prepare themselves better against competitors.
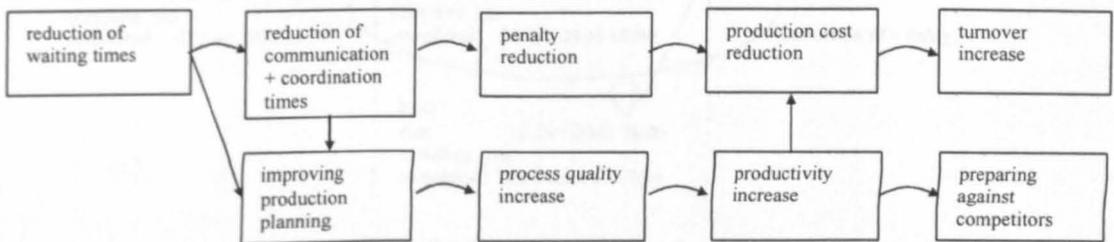

Figure E.8: Economic effects of detecting and reducing waiting times

IV. Evaluation result

operational criteria	timing				costs			quality					future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
detecting and reducing waiting times	com,cor, w	+		+	+	low	low		+					+

Table E.13: Evaluation results for the scenario: Detecting and reducing waiting times

A direct reduction of waiting times is, as demonstrated in the described scenario, not possible. However, decision support for indirect reduction of waiting times is available and can be used if PDPM is correctly applied (see table E.13). Changing the production plans accordingly leads to more productivity and penalty savings. Usually, this influences slightly production costs and can lead in the long-run to a slight turnover increase. Waiting time reduction increases the process quality and prepares against competitors. Tests with the prototype have shown that waiting time can be detected and eliminated. However, manpower needs to be spent for these investigations and management will need to support this investment. The profitability of such time reductions is demonstrated in section 7.5.3.2.

E.1.6   Detect origin of delays

The aim in this section is to introduce and evaluate the scenario of how to detect the origin of delays. The loosely coupled approach enables this scenario because of the

availability of the data flow dependencies. To know the origin of delays helps to identify re-occurring production problems and assists with proposing catalogues of measures.
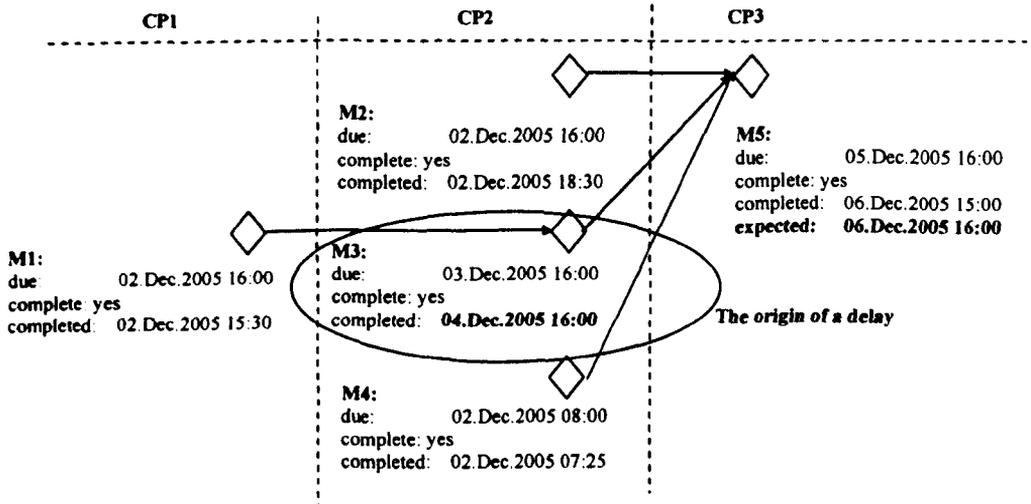
I. Scenario

Figure E.9: Example of detecting the origin of delays

When using the loosely coupled approach, it is possible to detect and mark milestones which are the origin of delays. When considering the aspects of exception reporting it is usually not of interest if, in thousands of milestones, one milestone is delayed once. It is also usually not of interest if it was a minor delay. However, if a delay is a re-occurring problem that has been monitored over several production periods or if it is a major delay, then the investigation and correction of this delay can help to reduce delays in the future. The detection of such origins is demonstrated in the example presented in figure E.9. In this example milestone M3 can be identified as an origin of delays. Its predecessor is not overdue but its successors are. It is important to notice that M3 is the trigger of the delay caused in M5, whereas the milestone M2, which is also late, has not triggered the delay caused in M5 and has thus not been defined as an origin of a delay. An algorithm for dealing with the complexity of this search process has been investigated for the prototype. Therefore, within the scope of this research project a diploma thesis was supervised that investigated amongst others an algorithm for detecting the origins of delays (Stuchly, 2005, 48-52).

II. Operational consequences

As summarised in table E.14, this scenario especially helps in cases where delays are repeated in several production periods or if the consequences of delays have been tremendous. These cases can then be investigated and catalogues of measures can

be derived. Statistics about the origins of delays are possible and show correlations to strong or weak workflow segments. This gives the management clues about where process improvements could be necessary.

scenario: detecting the origin of delays	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence in 2.)
pre-conditions	delays are not documented and not traceable	delays are documented and are queried as the need arises	no	- re-occurring delays can be identified - strong and weak workflow segments can be easily identified
derived actions	origin of delays often unknown	origin of important delays are investigated		

Table E.14: Operational consequences of detecting the origin of delays

III. Chain of business effects

The knowledge of the origin of delays improves the production overview (see figure E.10). It also improves the production planning as similar delays may be prevented in future production periods. Penalty costs can be saved and the process quality improved. This prevents the PDP company against quality reductions.
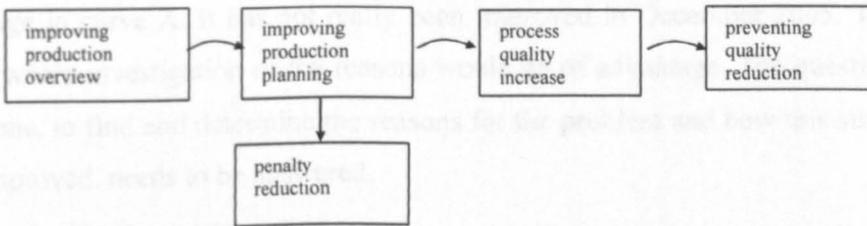

Figure E.10: Economic effects of detecting the origin of delays

IV. Evaluation result

operational criteria	timing				costs			quality					future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
detecting the origin of delays		+			low				++		+		++	

Table E.15: Evaluation results for the scenario: Detecting the origin of delays

The improved knowledge about production that is triggered by this scenario especially enhances the process quality and prevents thus quality reductions (see table E.15). However, the pure knowledge alone does not improve PDP. The knowledge of the origin of delays must be used to take adequate actions. These actions indirectly influence production planning in a positive way. The analysis of delays accordingly strengthens the production overview.

E.2 Strategic and tactical level

E.2.1 Due date adherence

The scenario presented and evaluated in this section discusses how the productivity in PDP can be increased. The adherence of due date can be used to measure the behaviour of the productivity in PDP and is thus a key performance indicator for productivity.

I. Scenario:

As introduced in section 6.3.4.4 the adherence of due dates can be used to measure the progress in PDP. The loosely coupled approach supports these measurements as demonstrated with the prototype. In figure E.11 an example of such a measurement is presented. In this picture a scenario is demonstrated in which the value of completed delayed milestones (i.e. curve C) at checkpoint CP3 in October 2005 was below the average of completed delayed milestones from all checkpoints (i.e. curve A). The situation changes dramatically in November 2005 where curve C climbs for twelve percent above its average in curve A. It has not really been improved in December 2005. This is a typical case where investigation of the reasons would be of advantage. The question of what can be done, to find and determine the reasons for the problem and how this situation then can be improved, needs to be answered.
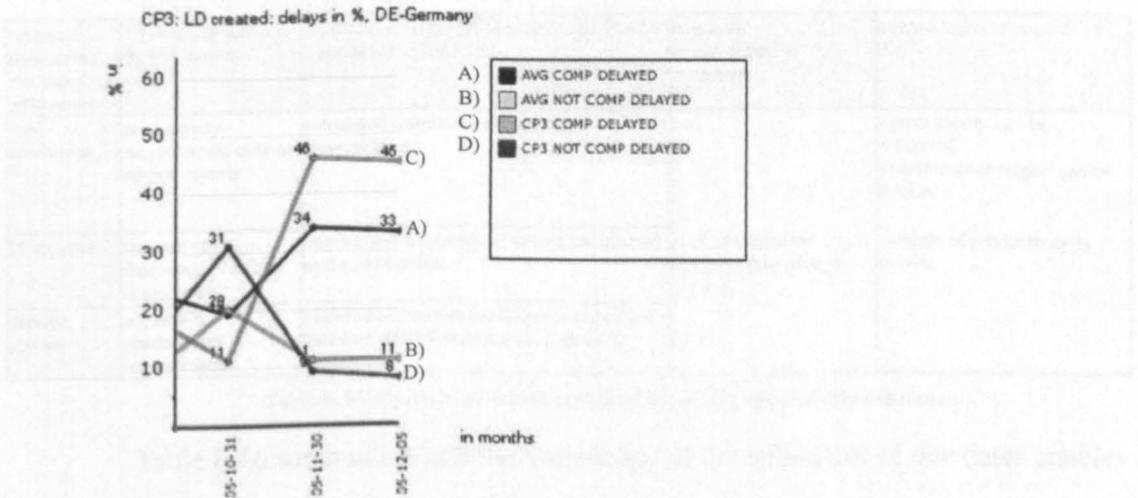

Figure E.11: Example of a productivity diagram

1. *Finding the source of the problem:* The first step identifying the problem sources is to query the milestones. This is, for example, possible with the Milestone Administration tool (see section 6.3.4.1) by using the sophisticated filters for searching completed, delayed milestones at checkpoint CP3 in the specific time frame November 2005. This

identifies the involved data packages as well as the responsible operators or working groups.

2. *Determining the reasons of the problem:* Usually, the responsible person knows the specific problems that have appeared within the working groups. A large range of possible reasons can be identified. For example, reasons could be PDP system breakdowns, PDP system utilisation which is too high, deviations of the data packages, or cases of illness of staff.

3. *Sanctions for improving the situation:* The necessary sanctions, which need to be derived after determining the reasons of the problem, depend highly on the reasons of the problem. In the following list possible sanctions are mentioned. Due to the high variety of possible problems this list only includes examples:

    - checking, reconsidering and changing organisational structures
    - postponing deadlines for delivering end-reports to customers, or postponing internal due dates of data packages
    - changing the order of the production of specific data packages
    - changing the priorities of specific data packages
    - searching and avoiding peak times in production
    - gaining the lost time of data packages in latter checkpoints
    - checking and reducing penalties
    - employing more production operators

II. Operational consequences

scenario: measuring the due date adherence	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
pre-conditions	productivity measurement only as ad-hoc reports	automated continuing productivity measurement	yes	- productivity can be measured - performance targets can be tracked
IT support	number and frequency of delays is unknown	number and frequency of delays are queried as the need arises	GUI: Production-Progress (see section 6.3.4.4)	- course of productivity is known
derived actions	unreliable productivity measurement	performance targets are formulated and are based on reliable values and progress is monitored		

Table E.16: Operational consequences of measuring the due date adherence

Table E.16 summarises that the knowledge of the adherence of due dates enables the analysis of the productivity in PDP. The management can determine performance targets. These performance targets can be tracked by observing the adherence of due dates. The consequence is that the course of the productivity over time is known and can be treated accordingly. Abnormalities regarding the productivity can be detected early. Strong and weak workflow segments can easily be identified.

III. Chain of business effects

The scenario to track the adherence of due dates over time improves the production overview (see figure E.12). As the rate of delays is known this consequently helps to improve production planning. Bottlenecks can be identified and due dates can better be planned accordingly. This also decreases peak loads as production critical days can be avoided. Flatten the fluctuations in production means that in the long-run the productivity and the process quality can be increased. PDP quality reductions can therefore be prevented more easily. A better controlled PDP process also helps to prepare against competitors.
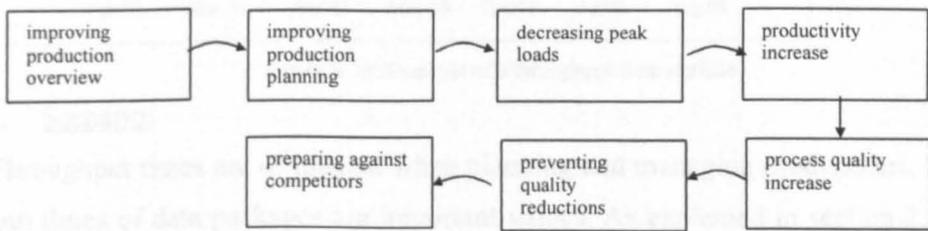

Figure E.12: Economic effects of measuring the due date adherence

IV. Evaluation result

The scenario presented in this section has demonstrated that the control of the due date adherence leads especially to an improvement of production planning and to a productivity increase (see table E.17). This improves highly the process quality and prevents respectively quality reductions. Successfully controlling of the PDP, prepares a company well against its competitors. Peak loads can moderately be decreased and the production overview is improved as the processes in PDP are better monitored and analysed. The assessment of the experts has shown that the productivity is a useful key performance indicator. However, the tests led to the conclusion that it might be advantageous to implement a possibility to drill-down fluctuations in the aggregated productivity curves for enabling fast cause studies.

operational criteria	Timing				costs			quality						future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
measuring the due date adherence		++	+	++					++		+		++	++

Table E.17: Evaluation results for the scenario: Measuring the due date adherence

E.2.2   Throughput time statistic

The scenario that is presented in this section demonstrates how throughput times can be measured by using the loosely coupled approach. The knowledge of throughput times advances the decision support while planning production or planning the sale of new

end-reports. Due dates can be more exactly estimated and production can be better controlled. Fluctuations in throughput times give also clues about the productivity in production.
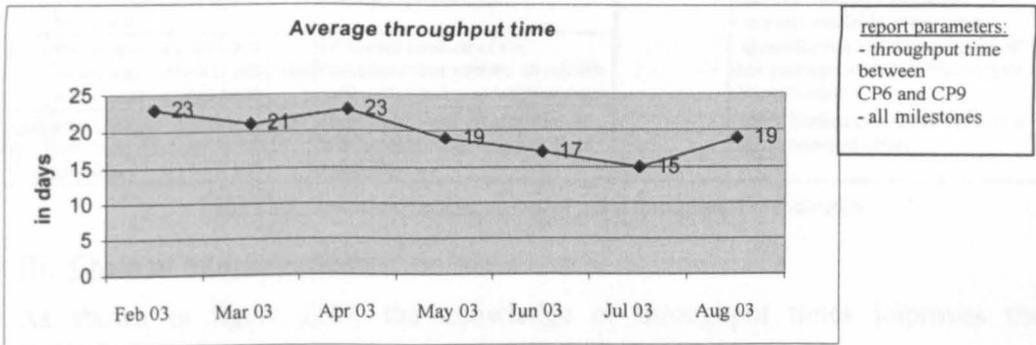

Figure E.13: Example of a throughput time statistic

I. Scenario:

Throughput times are of interest when planning and managing productions. In PDP throughput times of data packages are important values. As explained in section 2.3.4 the throughput times have to be interpreted in PDP for a specific unit. A unit can be one milestone or a group of milestones. The differentiation of the unit can be done by filtering the milestone dimensions (e.g. product-groups, periods or the specification of retailers). To enable the filtering a checkpoint has to be defined as starting point. Another checkpoint can be defined as endpoint. The throughput time is then determined by considering the completion dates of specified milestones and the predecessor- and successor relationships between the milestones. The throughput times are averaged if more than one milestone was specified. Usually, statistics about the development of throughput times over a specific timeline are of interest. This is demonstrated in the example shown in figure E.13. In this example a monthly overview of the average throughput time between checkpoint CP6 and CP9 is shown for all milestones. The completion date can be used to specify that a milestone belongs to a certain month.

II. Operational consequences

Table E.18 summarises that measuring throughput times reliably means that investigations about data packages with long throughput times can be initiated. End-reports with high production efforts and long throughput times can be investigated for their relevance and their costs. The production control can be advanced and planning can be improved when throughput times are known.

scenario: using throughput time statistics	1.) situation without PDPM system	2.) situation with PDPM system and PDPM information is used	scenario implemented in prototype	operational consequence of 2.)
pre-conditions	throughput times cannot be measured because relationships between data packages are unknown	throughput times are measured, because relationships between data packages are available	no	- increased knowledge of throughput times - statistic reliably calculated - statistic available at any time
IT support	throughput time statistics where only manually calculated ad-hoc and by estimation	automated creation of the throughput time statistic on reliable predecessor successor relationships		- identification and investigation of data packages with long throughput times possible
derived actions	identification of data packages with long run times is hardly possible	identification and investigation of data packages with long run times is possible		- identification of end-reports with a high production effort

Table E.18: Operational consequences of using throughput time statistics

III. Chain of business effects

As shown in figure E.14, the knowledge of throughput times improves the production overview. Throughput times can be used to advance production planning as the coherences in PDP become clearer. If throughput times are known, this can also help to reduce peak loads and to avoid bottlenecks. Production performance can be increased and process quality is positively influenced. This prevents PDPs against quality reductions.
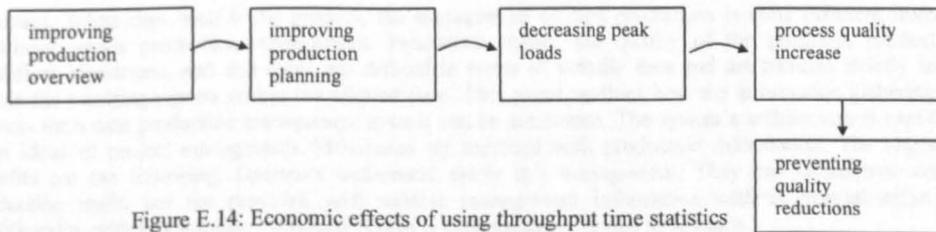

Figure E.14: Economic effects of using throughput time statistics

IV. Evaluation result

Throughput times measured in this approach are related to milestones and thus to several production jobs at once. Although the throughput times are not measured at the job level, the information of a throughput time on the milestone level is detailed enough. It is possible to filter the throughput time for all milestone dimensions (e.g. product-groups, delivery types, etc.). This gives detailed insights into the behaviour of the production.

operational criteria	timing				costs			quality						future-orientation	
benefits	reduction of times	improving production planning	decreasing peak loads	productivity increase	penalty reduction	turnover increase	production cost reduction	product quality increase	Process quality increase	enabling traceability	improving production overview	improving customer satisfaction	preventing quality reduction	preparing against competitors
using throughput time statistics		+	+						++		+		++	

Table E.19: Evaluation results for the scenario: Using throughput time statistics

The evaluation result of this scenario is that the investigation of throughput times in PDP can excellently be used to improve the process quality and correspondingly prevents quality reductions (see table E.19). The knowledge of throughput times is useful to improve the planning and to decrease peak loads. The production overview is increased due to a better understanding of throughput times in PDP.