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4 **Lockdown in Maharashtra, India**

5
6 **Abstract**

7 To prevent the pandemic spread of human-to-human transmitted diseases such as Covid-19,
8 governments commonly resort to countrywide or regional lockdown strategies. The lockdowns, whenever
9 and wherever implemented, curtail the movement of persons and vehicles, and drastically alter traffic
10 conditions. Our study focuses on the effect of drastic and sudden changes in the traffic conditions during
11 the Covid-19 lockdown in the state of Maharashtra in India, in March-June 2020, on the numbers of motor
12 vehicle accidents (MVAs), and the resultant fatalities and injuries. We carry out content analysis of police-
13 reported first-information-reports (FIRs) of MVAs, and compare these lockdown trends with archival data
14 from corresponding previous (normal) periods. Our statistical analysis shows that during the lockdown,
15 while the total number of MVAs fall drastically, they are more severe and have a much higher fatality rate
16 per MVA. Also, the pattern of vehicles involved in MVAs, and resultant pattern of fatalities also changes
17 during lockdowns. We explore the reasons for these changed patterns and provide suggestions to reduce
18 these negative externalities of pandemic related lockdowns.

19
20 **Keywords:** Covid-19 pandemic; Lockdown; Motor Vehicle Accidents; Fatalities; India; police-
21 reported crashes; police first-information-reports

Analysis of Motor Vehicle Accidents: Comparison Between Before and During the Covid-19 Lockdown in Maharashtra, India

INTRODUCTION

As wave after wave of the Covid-19 pandemic waxes and wanes through almost every country in the world, a common response of most governments has been periodic impositions of nationwide or regionally localized lockdowns (1). The occurrence of a human-to-human transmitted pandemic disease often brings about regulatory changes (such as lockdowns) to control the spread of the disease. These lockdowns essentially restrict the movement of persons, and are aimed at reducing person-to-person contact, and thereby slowing down the spread of the pandemic (2).

The Covid-19 pandemic originated in China in late 2019 and is believed to have first arrived in India in early 2020 through incoming international travelers (3,4). In March 2020, the government of India (GoI) started aggressively combating the spread of the Covid-19 by screening and quarantining international travelers. On 25th March, GoI imposed a strict nationwide lockdown (5,6). It was among the strictest lockdowns anywhere in the world (5). In the early part of the lockdown, India scored 100 points (i.e. the maximum score possible) on the Stringency Index developed by the University of Oxford (5). The GoI banned public events, ordered social distancing measures and stay at home policies, and mandated closure of workplaces, businesses, and schools. It imposed strict restrictions of all public and private vehicular movements all across the country (6). That most citizens complied with the lockdown, and vehicular movement was significantly restricted, is well documented (7,8). It is also triangulated from the reduction in the sales of petroleum products (9), and the reduction in air pollution levels (10) in these months. The regulations applicable in the lockdown's four sub-periods, and the evolving on-the-ground traffic conditions are described in Appendix-A.

People accept and support government-imposed travel restrictions to control the spread of epidemics (11). The lockdowns, and associated travel bans, whenever and wherever they are implemented, drastically alter the traffic conditions and mobility patterns on the roads. The shift in mobility patterns is further affected by country-specific factors like infrastructural development, demographics, social and economic factors that significantly impact road safety (12). Hence, it is important to study the change in mobility patterns and the associated motor vehicle accidents (MVAs), fatalities and injuries to highlight how the lockdowns are different from normal road conditions. An understanding of these differences will aid in designing appropriate road safety policies for these uncertain times (13).

Under normal conditions (i.e. without lockdowns), the increasing trend in the number of MVAs and the resultant over 1.2 million annual fatalities and many more injuries are serious global challenges (14,15). Naturally, most extant research on MVAs focuses on the normal traffic conditions on the roads. For instance, past research has delineated numerous causes why MVAs take place, and identified the factors that affect the number of MVAs and their severities. These factors include those related to vehicles' characteristics, driver characteristics, safety equipment, environmental conditions, regional aspects (rural/urban), psychosocial factors, and lifestyles of persons involved (16–19). However, there is scant literature exploring the impact of drastic and sudden changes in the traffic conditions (as is the case in a lockdown in a region) affecting the numbers, types, severities of MVAs and resultant fatalities taking place there. This exploratory study aims to bridge this gap.

The overall lockdown in India was further subdivided into four sub-periods referred to as lockdown 1.0 (of 21 days duration), lockdown 2.0 (19 days), lockdown 3.0 (14 days) and lockdown 4.0 (14 days). In this timeframe, there were drastic, rapid, and evolving regulatory changes that severely altered traffic conditions and restricted the movement of persons, goods and vehicles by roadways in India (6). The rules and regulations governing the mobility of persons and motor vehicles changed from phase-to-phase through

the four lockdown sub-periods. The lockdown started off as a complete shutdown (5). Over time, it turned into a partial lockdown as various permissions were gradually granted for movement of people and goods by roads. Thus, the severity of the lockdown varied across its four phases (20). Accordingly, the traffic conditions on the roads were varied, as though, through a natural experiment. These changed traffic conditions include the volume of vehicles plying, vehicles mix, vehicle usage patterns, and the persons traveling, and had a differential impact on the MVAs during the various phases of the lockdown.

We explore whether the number of MVAs, the fatalities and injuries therefrom, the types of vehicles involved, the roadway types where MVAs occurred, and the time-of-day pattern of MVAs were different during the Covid-19 lockdown as compared to the averages from previous normal periods. We focus on Maharashtra state in India which previously under normal circumstances in 2018, had witnessed 35,717 MVAs (7.7% of all MVAs in India) and had the dubious distinction of occupying the second rank among all states in India with 13,261 MVA fatalities (8.8% share of fatalities) (21). Drawing upon extant literature, we examine the reasons for the changed patterns observed. In addition, our study compares and contrasts various sub-phases of the lockdown itself to understand the changes at a micro level.

Until widespread vaccination takes place or a specific cure is available for the Covid-19 pandemic, periodic geographical lockdowns of populations are expected to continue as one of the mitigation approaches to curb the pandemic's rapid spread. Our study provides guidance to policy makers, traffic police, and roadway administration personnel on how such lockdowns can be better planned and implemented to minimize negative externalities on the roads.

THE NORMAL CONDITIONS ON INDIAN ROADS

MVA related fatalities and injuries are a major and growing problem in India (22). For many years now, India is among the countries with the largest number of MVAs and related fatalities in the world. In 2018, India had 151,417 fatalities (or one person killed every 3.47 minutes) as a result of 467,044 MVAs (21). Of the 199 countries covered in the World Road Statistics, 2018, India ranked 1st in the number of MVA fatalities and accounted for 11% of all MVA fatalities in the world (23).

Extant research suggests that over speeding, and high density of traffic are among the key reasons for MVAs. Fatalities and serious injuries are related to crash severities (24). Some of the key factors that affect crash severities in MVAs include drinking and driving, over speeding, reckless driving, seat belt non-usage, absence of traffic controls at intersections, poor weather conditions, traffic volume, and the period of time of day (25,26).

Among the main reasons for MVAs in India and for the high percentage of fatalities, the most prominent ones included over-speeding, unsafe vehicles, lack of infrastructure for pedestrians and cyclists and increasing volume of traffic (21,23). In 2018, about 55.3% (258,413 in number) of all MVAs, about 62.5% of all MVA fatalities (94,626 fatalities), and 55.9% of all injuries (i.e. 262,201 injuries) in India took place on the national and state highways (21). Given that national highways (1.9%) and state highways (2.9%) only comprise of less than five percent of the overall Indian road network, highways in India are disproportionately risky. In 2018, vehicle-to-vehicle collisions (54.3%) and MVAs involving vehicles and pedestrians (16.9%) accounted for the largest categories of MVAs by collision types.

Maharashtra state

With about 112 million inhabitants, Maharashtra is India's second most populous state. Geographically, it is the third largest state in India with a land area of 307,713 square kilometers. It has 44 cities that have populations over 100,000. In 2017, it had about 30.2 million registered motor vehicles. Maharashtra has about 267,452 kilometers length of surface roads, including 4,176 km of national highways and 3,700 km of state highways (27). In 2018, the national and state highways of Maharashtra witnessed 17,110 MVAs (6.6% of all MVAs on Indian highways) with 7,534 fatalities (7.9% of all fatalities on Indian highways), and 15,485 injuries in all (21).

METHOD

The study involved collecting and analyzing data from various sources. First, we carried out a systematic content analysis of police-reported FIRs of MVAs in Maharashtra during the lockdown period. Second, we accessed archival reports from the Ministry of Road Transport and Highways (MORTH), GoI, to understand the baseline MVAs in Maharashtra, under normal – i.e. non-pandemic conditions. Third, we studied relevant literature to explicate the potential causes of MVAs and fatalities.

Content analysis of police-reported FIRs of MVAs in Maharashtra

Database

In India, all MVAs are investigated by the state police. For each crash, a state police team carries out an initial investigation and prepares a FIR report, in which, using a standard templated format, details of the vehicles involved, road conditions, road-users behavior, etc. are recorded (refer Appendix B for FIR template). We obtained police-reported FIR data in Maharashtra state from the Crime and Criminal Tracking Network & Systems (CCTNS) database. The CCTNS is a project implemented by the Ministry of Home Affairs under the National e-Governance Plan (NeGP) of the GoI (28). The search date-range criteria were limited to the Covid-19 lockdown period and resulted in the retrieval of 55,957 police-reported FIRs in all (for all reported crimes) in Maharashtra from 25th March 2020 to 31st May 2020. Depending upon the nature of the MVA incident, the police-reported FIRs are classified according to the relevant sections of the Indian Penal Code and The Motor Vehicles Act¹. Accordingly, we conducted a Boolean search ['Motor Vehicles Act' OR '304-A' OR '338' OR '337'] of these FIRs, and obtained 775 FIRs that were related to MVAs. After cleaning the data to eliminate FIRs where the MVAs had taken place outside the lockdown period, we finally obtained, coded and analyzed FIRs of 761 unique MVAs.

Coding procedure and categories

Two researchers independently analyzed the FIRs manually. The codes were explained to the independent coders by the first author after coding an initial percentage of the sample. After each researcher making an independent judgement and coding a randomly selected common set of 100 FIRs (about 13% in all), both researchers compared their coding results, discussed, and resolved differences. Then, using a common coding-frame (described below), the 761 FIRs was carefully content-coded. Agreement ratio, measured as the total number of agreed units by two coders to the total number of coded units, was used to assess the reliability of the coding process (29,30). The overall inter-coder reliability (0.96) was within the accepted range of 0.8–1.0 (30,31) and the differences in coding were examined and resolved by the authors. The coding instrument consisted of the date of MVA, type of roadway, impacting vehicle, impacted vehicle, number of fatalities (segregated by gender), number of injuries (by gender), traffic violation, time of day/night of MVA, and the location. The coding framework used is described in Table 1 below:

Table 1: Coding framework

#	Variable	Possible values	Notes
1	Lockdown phase	1, 2, 3, 4	As per the timelines defined by MHA
2	MVA Date	Date value	The date when the MVA occurred
3	MVA Time	Time value	The time when the MVA occurred. We classified the MVAs as having occurred in the <i>daytime</i>

¹ In India, police-reported FIRs of motor vehicle accidents typically include one or more of the following sections of the Indian Penal Code, (a) Section-304A: Rash and negligent act resulting in death; (b) Section-338: Cause grievous hurt by act endangering life or personal safety of others; (c) Section-337: Cause hurt to any person by doing any act so rashly or negligently as to endanger human life, or the personal safety of others; and the following sections of the Motor Vehicles Act, (i) Section-184: Drive a motor vehicle at a speed or in a manner which is dangerous to the public; (ii) Section-134: Duty of driver in case of accident and injury to a person

			(between 6 AM to 6 PM) or at <i>night</i> (6 PM to 6 AM) based on the MVA incident time mentioned in the FIR.
4	roadway-type	(1) highway (2) other	If the MVA occurred on a national or state highway, the MVA roadway-type was coded as <i>highway</i> , else as <i>other</i> .
5	Impacting vehicle category	2-wheeler; 3-wheeler; 4-wheeler; truck; bus; others	The vehicle mentioned in the FIR to have caused the MVA, or the only vehicle involved in the MVA was coded as the <i>impacting</i> vehicle.
6	Impacted vehicle category	2-wheeler; 3-wheeler; 4-wheeler; truck; bus; others	If more than one vehicle was involved, the vehicle other than the impacting vehicle was coded as the <i>impacted</i> vehicle.
7	# of fatalities (male)	Number	Number of male fatalities in the MVA
8	# of fatalities (female)	Number	Number of female fatalities in the MVA
9	Total # of fatalities	Number	Total number of fatalities in the MVA
10	# of injuries (male)	Number	Number of male injuries in the MVA
11	# of injuries (female)	Number	Number of female injuries in the MVA
12	Total # of injuries	Number	Total number of injuries in the MVA
13	Traffic violation	Reckless driving; over-speeding; drunken-driving etc.	As per the reason of the MVA mentioned in the text of the FIR
14	Location of MVA	Place	As per the place of the MVA mentioned in the text of the FIR

Archival government data and statistical analyses

The MORTH, GoI publishes an annual report titled ‘Road Accidents in India’. The most recent report covers MVAs in India in 2018 (21). Data from this report was used as a comparison set representing normal conditions on Maharashtra’s roads. We used analysis of variance (ANOVA) and t-tests to compare the two sets of data (32).

RESULTS AND DISCUSSION

The study aims to explore the differences in the patterns of MVAs, fatalities, and injuries during the Covid-19 lockdown when compared to previous normal-traffic-conditions periods. Below, we discuss the findings from our analysis.

Number of MVAs across lockdown stages

Our data revealed that during the 68 days long lockdown in Maharashtra, 761 MVAs occurred, resulting in 360 fatalities and 859 injuries. During the lockdown, the daily average number of MVAs (11.19) fell drastically by 88.6% compared to the daily average MVAs (97.85) in Maharashtra in 2018. Starting with a near complete absence of traffic in lockdown 1.0, in each subsequent phase of the lockdown the restrictions were eased somewhat. ANOVA tests reveal a significant difference ($F = 70.12$ at 1% significance) in the daily average number of MVAs across phases (also refer Figure-1), with phase 3 (mean

= 23.79, s.d. = 6.03) and phase 4 (mean = 19.93, s.d. = 5.46) having significantly higher MVAs per day compared to phase 1 (mean = 1.60, s.d. = 1.90) and phase 2 (mean = 7.00, s.d. = 3.21).

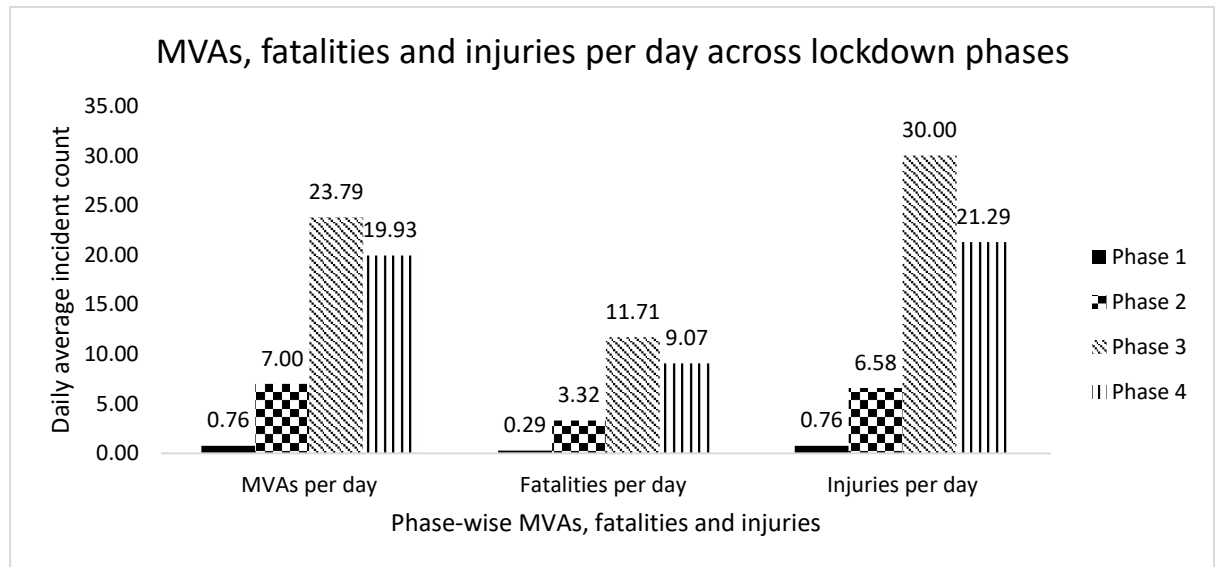


Figure 1: MVAs, fatalities and injuries per day in different phases of lockdown

These daily averages, however, are much lower than Maharashtra's averages in 2018. This finding is aligned with previous research that the daily average number of MVAs are affected by the total traffic volume on the roads (33). Phase 3 of the lockdown saw the highest average of 23.79 MVAs per day.

Table 2: Comparison of 2020 lockdown with baseline data from 2018

		2020 lockdown	Comparison 2018
Day/ Night split of MVAs, fatalities, and injuries			
Number of MVAs	Day	471 (61.89%)	3,724 (55.96%)
	Night	290 (38.11%)	2,930 (44.04%)
Number of fatalities	Day	222 (61.67%)	NA
	Night	138 (38.33%)	NA
Number of injuries	Day	470 (54.71%)	NA
	Night	389 (45.29%)	NA
Average number of MVAs, fatalities and injuries			
Daily average number of MVAs		11.19	97.85
Daily average number of fatalities		5.29	36.33
Average # of fatalities per MVA	t-stat 2.70***	0.47	0.37
Average # of injuries per day		12.63	85.93

		2020 lockdown	Comparison 2018
Average # of injuries per MVA	t-stat 2.83***	1.13	0.88
***: significant at 1%, one-sided p-value			
MVAs by road-type			
MVAs on highways		542 (71.22%)	3,188 (47.91%)
MVAs on other roads		219 (28.78%)	3,467 (52.09%)
Total MVAs		761	6,654
Fatalities by gender			
Total # of fatalities (male)		N = 323 (89.7%)	N = 2,152 (87.1%)
Total # of fatalities (female)		N = 37 (10.3%)	N = 318 (12.9%)
Total # of fatalities		360	2,471

2 Number of fatalities and injuries

On an average, in 2018, MVAs in Maharashtra resulted in 36.3 fatalities per day. In comparison, due to severely reduced traffic volumes during the 2020 lockdown, Maharashtra witnessed an average of only 5.3 fatalities per day, indicating an 85.4% reduction. However, the ratio of fatalities per MVA, which was 0.37 in 2018 (21), jumped up significantly by 1.27 times to 0.47 in the 2020 lockdown. Similarly, the ratio of average number of injuries per MVA saw a significant 28.4% increase from 0.88 in 2018 to 1.13 during the lockdown, indicating higher average MVAs' severities. The change in the pattern of the number of fatalities per MVA (and injuries per MVA) during the lockdown was observed because of the following reasons.

First, there was a greater chance of over speeding and reckless driving due to relatively vacant roads during the lockdown (13,34). Second, in India, overcrowding and overloading of vehicles is a perennial problem leading to about one fifth of all MVA fatalities (22). During the lockdown, many of the commercial vehicles involved in MVAs were overcrowded with migrant workers and carrying more passengers than usual/ allowed leading to fatalities (35). Third, during the lockdown migrant workers illegally travelled in trucks and goods carriers without safety precautions (36). Finally, due to bystander apathy and reluctance to get involved with police procedure, MVA victims in India may not receive timely rescue/ help (37). During the lockdown, fewer people were on the roads and this may have led to more than usual delays in providing roadside first-aid to MVA victims (38).

Effect of the time of day and gender

In Maharashtra, during the Covid-19 lockdown, due to strict enforcement of night-time curfew, we found that 61.9% of all MVAs (2018 proportion: 55.9%) occurred during the day-time hours (6am to 6pm) (see Table 1). In the lockdown period, while 61.7% of all fatalities occurred during day-time hours, we found that the day-night split of fatalities per MVA ratio did not vary across day-time hours (0.47 fatalities per MVA) and night hours (0.48). The gender-wise distribution of fatalities did not change significantly during the lockdown as compared to the gender-wise distribution in 2018 (21).

Distribution of fatalities and injuries across lockdown phases

The daily average number of fatalities and injuries followed a similar pattern to that of MVAs (see Figure-1). Fatalities and injuries varied by phase of lockdown and peaked in lockdown 3.0 (see Table 2). The lockdown 3.0 phase was most dangerous among the four phases as it saw 11.71 fatalities per day against an overall lockdown average of 5.29, and 30 injuries per day (overall lockdown average of 12.63). ANOVA and t-tests revealed significant differences (at 1% significance) in the average number of fatalities per day

and injuries per day across phases of the lockdown. However, for fatalities, statistically significant difference was not observed between phase 3.0 and phase 4.0 of the lockdown.

Table 3: Comparison of daily average number of fatalities and injuries across lockdown phases

		Fatalities				Injuries			
Lockdown phase		Tests of differences between phases (t-statistics)	Mean	s.d.	F	Tests of differences between phases (t-stat)	Mean	s.d.	F
Phase 1	Phase 2	(-5.70)***				(-4.66)***			
	Phase 3	(-8.55)***	0.60	0.70		(-7.04)***	1.60	2.32	
	Phase 4	(-9.77)***				(-14.06)***			
Phase 2	Phase 3	(-6.16)***	3.32	1.92	35.45***	(-5.80)***	6.58	3.39	35.85***
	Phase 4	(-6.02)***				(-10.33)***			
Phase 3	Phase 4	(-1.71)	11.71	4.83		(2.10)*	30.00	14.83	
Phase 4			9.07	3.17			21.29	4.46	

* $p < 0.05$ and *** $p < 0.001$; s.d.: standard deviation

Distribution by type of roadway

Our data reveals that during the lockdown, the total daily average number of MVAs drastically decreased on both highways and other roads in comparison to 2018. Also, highways recorded a greater number of MVAs than other roads, and this data shows an increasing trend as the lockdowns were progressively made less stringent in each successive phase.

An interesting observation is that a greater number of fatalities/MVA was observed on ‘other roads’ as compared to ‘highways’ during phase 1 and phase 2 of the lockdowns. A possible explanation is that phase 1 was the most stringent of all the lockdown phases and was announced and implemented suddenly at short notice. In a large country such as India, it is not possible to implement such restrictions uniformly across all roads. With restricting inter-city travel being easier to manage and also carrying relatively higher visibility, naturally, in lockdown 1.0 and 2.0, the highways immediately witnessed heavy police patrolling and barricading, and thereby minimal traffic, and lower average vehicle speeds (Appendix A). As a result, highways witnessed less severe accidents and thereby fewer fatalities and injuries in lockdown 1.0 and 2.0.

In comparison, other roads had lesser on-the-ground police enforcement, and therefore witnessed a relatively less change in the traffic patterns. Thus, there were more fatalities/MVA observed in other roads as compared to highways during phase 1 and phase 2 of the lockdown. Phase 3 and phase 4 of the lockdowns were relatively less restrictive (refer Appendix A), allowing for both increased vehicular traffic and higher average vehicle speeds on highways, thereby showing a divergent trend of fatalities/ MVA from phase 1 and phase 2.

On an overall basis, during the lockdown highways in Maharashtra witnessed a daily average of 7.97 MVAs as against 3.22 MVAs per day on other roads (refer Table 3). Also, crashes on highways were more severe and resulted in an average of 0.51 fatalities per MVA (as against 0.38 per MVA on other roads), and 1.24 injuries per MVA (as against 0.46 per MVA on other roads). Also, compared to 2018,

highways in Maharashtra were even more unsafe during the lockdown, with 71.2% of all MVAs (2018: 47.9%), 76.7 % of all fatalities (2018: 56.8%), and 78.4 % of all injuries (49.4 % in 2018).

Table 4: Average MVAs, fatalities and injuries per day and per MVA: By road type

	Road type	Lockdown 1.0		Lockdown 2.0		Lockdown 3.0		Lockdown 4.0		Lockdown Overall		t-stat ^a
		Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	
MVAs per day	Highways	0.57	1.89	4.95	2.66	17.07	4.50	14.07	3.20	7.97	6.79	5.31***
	Other roads	0.19	-	2.05	1.41	6.71	2.73	5.86	3.18	3.22	3.16	
Fatalities per MVA	Highways	0.17	0.39	0.46	0.48	0.56	0.49	0.50	0.47	0.51	0.48	0.28 (n.s.)
	Other roads	1.00	-	0.51	0.51	0.33	0.47	0.35	0.48	0.38	0.49	
Injuries per MVA	Highways	1.17	0.33	1.07	0.43	1.38	0.44	1.16	0.42	1.24	0.43	0.37***
	Other roads	0.50	0.58	0.49	0.49	0.45	0.45	0.45	0.45	0.46	0.46	

***: significant at 1%, two-sided p-value; n.s.: not significant; s.d.: standard deviation
^a t-statistics compare "Lockdown Overall" data for highways vs. other roads

Vehicles involved in MVAs

In 2018, in Maharashtra, two-wheelers were involved in largest number of MVAs (38.5 %) (see Figure-2) and resulted in 44.8 % MVA fatalities (see Figure-3) among all vehicle categories (21). However, in the 2020 lockdown in Maharashtra, most two-wheelers (which are typically used for employment-related daily commuting and other personal intra-city movement) were off the roads and thus two-wheelers only accounted for 14.8 % of MVAs (third ranked vehicle category) (refer Figure-2).

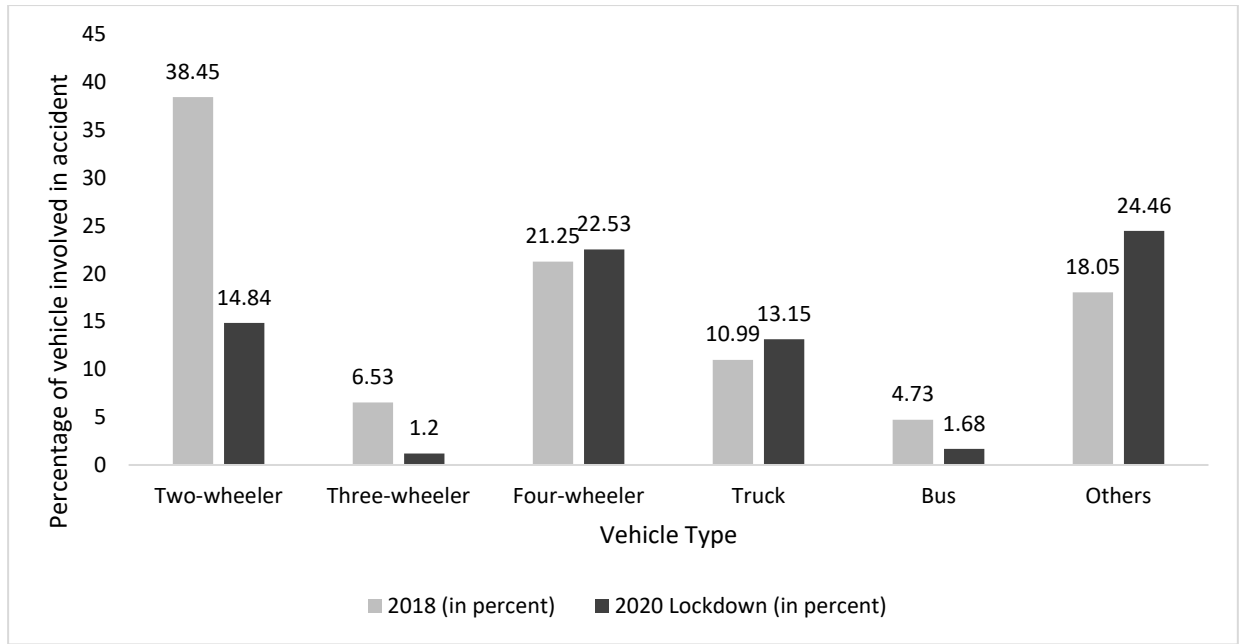


Figure 2: Percentage comparison of vehicles involved in MVAs (lockdown versus 2018)

However, even during the lockdown, most fatalities (35.7%) occurred in MVAs that involved two-wheelers (refer Figure-3). In the lockdown, the proportion of both MVAs (22.5%) and fatalities (20.6%) involving four-wheelers (comprising of cars, taxis, sports utility vehicles and tempos) went up from their 2018 figures (MVAs: 21.3%, fatalities: 14.3%) in Maharashtra.

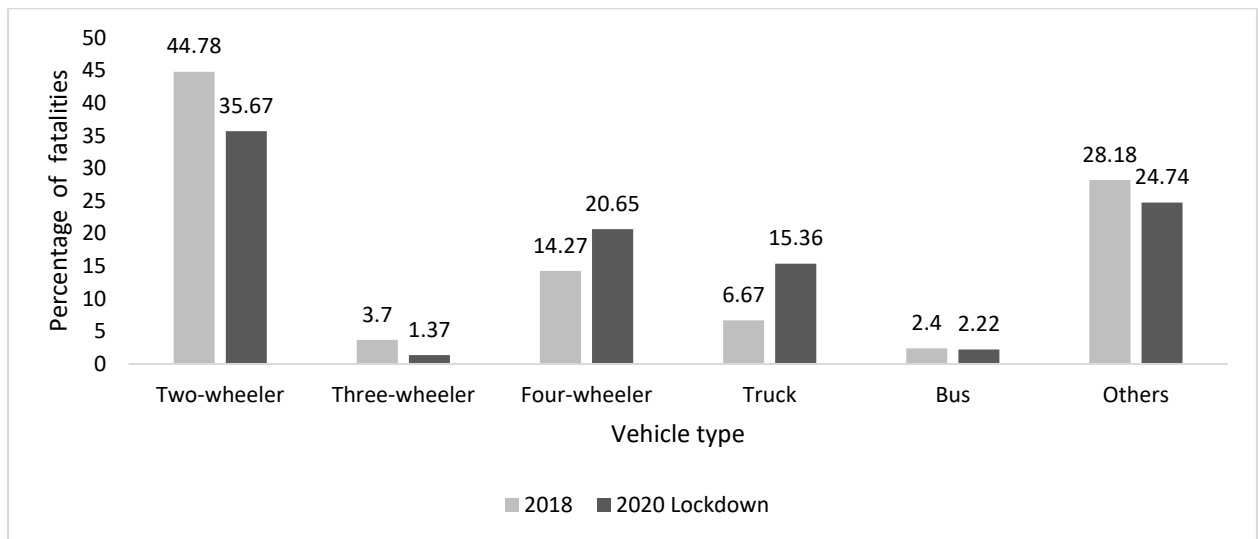


Figure 3: Percentage comparison of fatalities by vehicle type (lockdown versus 2018)

In the lockdown, trucks were involved in 13.2% of all MVAs (2018: 10.9%), that resulted in 15.4% of all fatalities, much higher than the 6.7% fatalities in 2018. In the lockdown, vehicle-to-pedestrian crashes increased to 19.2% of all MVAs (2018: 16.9%), and pedestrian fatalities were 17.8% of all MVA fatalities in the lockdown (2018: 14.9%).

During the lockdown, the proportion of MVAs involving a single vehicle (such as vehicle overturning, impacting a fixed object, or running off the road) fell to 19.1% of all MVAs (2018: 27.1%), as did fatalities resulting from such single vehicle crashes (lockdown: 24.7% of all fatalities; 2018: 30.9%). However, the ratio of fatalities per MVA in single vehicle crashes increased significantly from 0.35 in 2018 to 0.61 in the lockdown. This indicates that during the lockdown, while fewer vehicles were on the roads, those involved in single-vehicle crashes were likely to be carrying more persons, and probably traveling at higher speeds than normal, thus resulting in more severe crashes.

Changes to factors affecting MVAs, fatalities, and injuries (during the lockdown)

In light of the factors detailed in extant literature on MVAs in India (39,40) and on our findings, we discuss the possible factors affecting MVAs, fatalities, and injuries during the lockdown.

Changes to traffic volume, density and vehicles mix during lockdown

Our data showed that over-speeding and reckless driving were the most common reasons for MVAs, fatalities and injuries during the lockdown. Previous research highlights that lower traffic volumes leads to fewer total number of MVAs in any period, which is reflected in our study as well (33,41). However, when traffic volume is lower, average speeds tend to increase leading to higher severity of MVAs, and a higher average number of fatalities per MVA and injuries per MVA (13,33,41).

An explanation for a change in injuries/deaths per MVA, as highlighted by our data, is the shift in vehicle types (as seen in Figures 2 and 3) on the roads. During the lockdown, most of the two-wheelers were off the roads. This meant that the proportion of four-wheelers operating on the roads increased (42). Previous research states that the momentum and speeds associated with four-wheeler vehicles is relatively higher than those of two-wheelers (43). Thus, during the lockdown, when there were proportionately more four-wheelers on the roads, MVAs were more severe and resulted in elevated injury/mortality levels compared to those in 2018 (when the two-wheeler vehicles on the roads were proportionally higher).

Another explanation for the higher than normal fatalities per MVA and injuries per MVA ratios during the lockdown may relate to the change in the driver types on the road. For instance, while a risk averse individual may avoid driving during lockdowns, individuals with higher risk tolerance may continue to ignore the lockdown restrictions and Covid-19 risks, and also engage in risky driving behavior (13,44). Thus, our study highlights that in the lockdown in Maharashtra, the daily average number of MVAs was significantly lower than under normal traffic conditions, while the severities of the MVAs, and the rates of fatalities and injuries were much higher.

Lockdown conditions leading to over-speeding

Only trucks carrying essential commodities and emergency vehicles were allowed in the first phase of the lockdown (1.0). Even in the subsequent phases of the lockdown, there were significantly fewer vehicles on the road when compared to the usual traffic volumes in India.

With most of the traffic off the roads, the relatively few two-wheelers, four-wheelers, truck/ bus drivers plying during the lockdown were faced with roads that were almost empty. This was a highly unusual traffic condition in a highly and densely populated country such as India. For example, the average speed for trucks on Indian highways in normal circumstances is only 50-60 kilometers per hour due to high traffic density and mixed modes of vehicles traveling together (22,45).

When Indian drivers find less traffic on roads, they tend to overspeed (46), which is what is what happened during the lockdown (35). Given the poor maintenance and often poor condition of the rather old average vintage of vehicles in India (especially so for commercial vehicles) (46), over speeding carries high risk of loss of control of the vehicle, resulting in severe MVAs with higher fatalities per MVA.

Also, movement of trucks and other freight carrying vehicles was relatively uninterrupted during lockdown. Our data highlights that during the lockdown, trucks were involved higher than usual proportion

1 of MVAs, that resulted in greater than usual percentage of all fatalities (compared to 2018). This may be
2 because during the lockdown there was an increased preference for people to procure their shopping needs
3 through e-commerce platforms (47), resulting in trucks and freight carrier vehicles having to drive more
4 aggressively than usual for timely delivery (39).

5 *Greater than usual driver fatigue*

6 Past research indicates that about 1% to 3% of all MVAs are a result of driver fatigue, tiredness
7 and sleepiness (14,48). In general, Indian drivers are known to often be fatigued, tired, and sleepy due to
8 long working hours (22,46,49). During the lockdown, this was exacerbated as given the uncertainties on
9 regulatory restrictions, truck owners often pushed drivers to work longer hours and complete trips faster,
10 with resultant driver fatigue leading to MVAs with fatalities (35,50).

11 Recent research has highlighted that the Covid-19 pandemic and resulting economic downturn
12 affects driver behaviors (44). The initial stringent phases of the lockdown saw the temporary closure of all
13 roadside restaurants and motels. This resulted in drivers on highways not having access to their usual rest-
14 stops and food sources. This increased the drivers' anxiety, fatigue and stress levels resulting in increased
15 risk of MVAs. This is especially true for truckers who face increased stress to meet heightened expectations
16 to meet freight-demand (51) during lockdowns. Thus, it is of utmost importance to take care of the physical
17 and mental well-being of the drivers, and actions in this direction will help minimize the accidents during
18 the pandemic (52).

20 *Poorer than usual vehicular maintenance*

21 Indian vehicles in general (and commercial vehicles in particular) often are old and poorly
22 maintained (46). However, there exists a large informal network of roadside repair and servicing shops
23 dotting the Indian highways for day to day servicing. These auto-mechanics/ shops provide running repairs
24 and service to most Indian vehicles as they travel on the highways. However, in the lockdown period
25 (especially phase 1.0 and 2.0) these informal repair shops were closed. This meant that many of the vehicles
26 may have been even more poorly maintained during the lockdown than normal times, leading to greater
27 chances of MVAs.

28 *Greater laxity than usual in enforcement of safety regulations*

29 Previous research states that "stringent law enforcement and appropriate compliance from the road
30 users can effectively lessen traffic-related fatalities in unprecedented times" (2). However, despite being
31 mandatory, many Indian four-wheeler drivers do not wear seat belts. In fact, many of the older vehicles do
32 not even have seat belts installed. This increases the risk of serious injuries and fatalities in the event of an
33 MVA in India (53,54).

34 During the lockdown, the increased proportion of fatalities in MVAs involving trucks was because
35 large number of migrant workers hitched rides on trucks carrying essential goods. These hitchhikers
36 traveled in the back of the truck (squatting on the floor of the truck, without restraining mechanisms). Some
37 trucks carried nearly 100 such passengers packed together (36). According to the FIRs we analyzed, when
38 these trucks met with an accident, the number of fatalities and injuries were higher than average because
39 the workers sitting at the back of the trucks had no safety equipment to protect them.

40 Similarly, while Indian regulations mandate two-wheeler riders to wear helmets, actual compliance
41 with this life-saving regulation is extremely poor, especially outside of metropolitan cities. The high fatality
42 rates involving two-wheelers during the lockdown can similarly be attributed to people not wearing helmets
43 (55,56).

44 **CONCLUSION**

We aimed to explore the changed conditions and changed mobility patterns on Maharashtra's roads during the Covid-19 lockdown, and understand how these differences affected MVAs and fatalities. We started with the assumption that the lockdown had resulted in a positive externality and made Indian roads safer. However, the data reveals a more complex outcome. We analyzed 761 MVAs that took place on roads in Maharashtra during the lockdown. Our study revealed that the total number of MVAs reduced significantly over previous periods (i.e. compared to non-locked down conditions). However, the data exhibited a trend of fewer but more severe MVAs (especially on highways) during the lockdown. These high severity MVAs caused several fatalities and injuries, and happened due to a variety of causes.

The lockdown changed the characteristics/ conditions on the roads in significant ways, and exposed drivers to unusual conditions. This led to many of them losing control of their vehicles. These changes included (a) significantly reduced total traffic, allowing drivers to overspeed; (b) minimal access to alcohol during the lockdown, and resultant reduced drinking and driving; (c) change in the composition of traffic, i.e. the mix of vehicles; (d) an unusually large number of passengers traveling unsafely by hitching rides on commercial goods vehicles; (e) overworked and fatigued drivers, due to long hours of continuous driving; and (f) relatively poorer than usual maintenance of vehicles. An interaction of these factors also may have caused many of the MVAs.

The changed traffic conditions resulted in (i) significant decrease in the number of MVAs per day; (ii) daily average numbers of MVAs, fatalities and injuries significantly rising as the lockdown stringency eased up, (iii) fatalities per MVA and the injuries per MVA showed a substantial increase during the lockdown period as compared to normal conditions, and (iv) majority of the MVAs occurred on highways, with higher number of fatalities and injuries per MVA on highways, as compared to other roads.

Implications for policy makers and roadways administrators

What can the Indian government and the national governments world over learn from our study? Faced with pandemic like situations, lockdowns are likely to be a common and repeated response. The governments and roadway administration personnel need to be cognizant of the dangers that arise when drivers are exposed to unusual traffic conditions and mobility patterns during lockdowns. Accordingly, the following mitigation actions can be considered during lockdown conditions to reduce the number of MVAs, and resultant fatalities and injuries.

Extant research has highlighted the effectiveness of mass media campaigns in reducing MVAs (57). The type of message (rational, emotional or fear-based appeal) and associated enforcement or incentives together with "the duration, intensity, timing and exposure of media placement" (58) are key variables affecting road-safety related mass media campaign effectiveness. For instance, extant research states that multiple, repeated exposures are needed to effectively convey a campaign message to the targeted audience (59). Our study revealed that increased over-speeding and reckless driving were major causes of severe MVAs, fatalities and injuries during the Covid-19 lockdown. This leads to a few key implications.

Most governments have limited budgets for running public awareness campaigns on a bouquet of social issues. In a pandemic such as Covid-19, a large proportion of this budget gets reallocated on an ad hoc basis toward Covid-19 awareness campaigns. This results in disruptions or reduction in ongoing or planned campaigns aimed at enhanced public awareness of road safety behaviors. Taking cognizance of this, governments should continue to run road safety public awareness campaigns during lockdowns focusing on over-speeding and reckless driving related messaging (60).

Extant research reveals that roadside intensification of police enforcement positively affects driver behavior and reduces MVAs and fatalities (61). Our study revealed that significantly reduced traffic volume and redeployment of traffic police on Covid-19 related duties led to average vehicle speeds going up on highways, thereby increasing the number of severe MVAs, fatalities and injuries. Thus, enforcement of

road-safety through police patrolling, barricading, creating check posts and strictly enforcing fines for over-speeding and other rule violations should continue through the lockdowns. If police force availability is reduced due to redeployment for other duties during Covid-19 pandemic, then the limited number of available police personnel should be deployed on highways and on selected accident-prone sites for greatest impact.

Further, the fines, penalties or punishments for violations such as over-speeding and rash or negligent driving should be significantly enhanced temporarily during lockdowns and this should be highlighted in the media campaigns. This will influence driver behavior and make the roads safer during lockdowns. While some of these mitigating tactics are anyway useful under normal traffic conditions, they become all the more crucial during lockdown situations during pandemics.

Limitations

A limitation of our study is that we only examined MVAs from Maharashtra state and therefore, our findings have limited generalizability to other countries globally. Future researchers can analyze data from other countries, as well as compare the trends across multiple countries to improve the generalizability of our findings.

We analyzed the data using ANOVA and pairwise t-tests, which help in highlighting the differences in the MVA pattern between lockdown and no-lockdown phases (32). However, the ANOVA based analysis is limited in its ability to recommend how lockdowns can be better planned. Future researchers can conceptualize and test models using regression or structural equation modeling with lockdown related traffic data to understand the strength of impact of individual factors on MVAs, fatalities and injuries.

Also, we compared average numbers of MVAs, fatalities and injuries that happened in the months of March to May of 2020 to those that happened during the whole year of 2018. Extant research states that there are some seasonal effects of weather on MVAs (62–64). However, the annual report on Indian road accidents published by MORTH, GoI only shares aggregate numbers for 2018. It does not provide granular month-wise numbers for most of the variables that we considered in our study (21). As a result, the study adjusted the annual values of 2018 for analysis, and is limited in not being able to account for seasonality/seasonal effects on MVAs. Limitations notwithstanding, our intent was to study the changed mobility patterns during the Covid-19 lockdown vis a vis normal conditions, and understand how these differences affected MVAs and fatalities, for which this work provides valid and significant answers.

Appendix-A: Regulations applicable in the four lockdown sub-periods

Lockdown 1.0 (21 days duration from 25th March to 14th April 2020):

To ensure nationwide uniformity, GoI issued centralized guidelines. In summary, all government and private establishments, places of worship, and educational institutions were to be closed (6). A few exceptions were made such as the defense forces, police, healthcare, food and grocery shops, banks, media, telecommunications, pharmacies, petrol pumps, and emergency services. Transportation services of all forms, i.e. air, railways, and roadways were to remain shut, except those for fire services, law and order, emergency services, and transportation of essential goods. The government allowed inter-state movement of goods/ cargo for domestic and export purposes, and granted exceptions allowing procurement and marketing of agriculture products, farming activities. Inter-state and intra-state movement of agriculture related machinery and equipment were allowed. Movement of persons was largely banned, with only a few exceptions allowed for emergency services and essential items. The movement of large number of migrant workers to reach their home towns was deemed as a violation of the lockdown. Obviously, there was some movement of vehicles on the roads without permissions, but this was minimum and often swiftly dealt with by the law enforcement agencies.

Lockdown 2.0 (19 days duration from 15th April to 03rd May 2020):

Most of the restrictions on activities and movement of people was continued from lockdown 1.0. Changes included nationwide permissions for all activities related to agriculture, fisheries, plantations, financial sector, social sector work, online education, government employment schemes, public utilities, government offices with limited staff, cargo movement, supply of essential goods and services, home delivery of products, media, information technology services, and ecommerce. Further, relaxation was provided for all industrial units in rural areas, manufacturing units with in house labor, continuous production units, and construction activity with in situ workers. The government announced that if a group of stranded migrant workers wished to return to their place of work within the state that they were currently located, government will make arrangement for transportation by buses. However, no official inter-state movement was allowed. Further, processes were laid out for easing movement of stranded migrant workers, pilgrims, students, and other persons. Overall, the roadways traffic, though somewhat eased compared to lockdown 1.0, continued to be restricted in this phase.

Lockdown 3.0 (14 days duration, from 04th May to 17th May 2020):

The country was divided district-wise into red, orange, and green zones based on the Covid-19 pandemic prevalence, with different restrictions applicable in each zone. For instance, in the red zones, intra and inter district plying of buses was not allowed. Movement of individuals was allowed only for certain permitted activities. Four-wheelers could carry a maximum of three persons (including the driver), while no pillion riders were allowed on two-wheelers. The Indian government addressed the situation of migrant workers walking on roads to get back to their native places. All departments were to ensure that the migrant workers traveled by special buses and trains and did not walk on the roads.

Lockdown 4.0: (14 days duration, from 18th May to 31st May 2020):

In this phase, inter-state and intra-state movement of persons by passenger vehicles and buses was allowed with special permissions. Specific geographical containment zones were created within the red-zone districts. All activities and movement of persons in and out of containment zones was disallowed. Outside of the containment zones, most normal activities were permitted. However, a nationwide night-time curfew was imposed from 7 pm to 7 am.

Appendix B – Police recorded First Information Report (FIR) template

FIRST INFORMATION REPORT (Under Section 154 Cr.P.C.)

1. District: Police Station.:
Year:
FIR No.: Date and Time of FIR:

2.

Sr. No.	Acts	Sections

3. (a) Information received at Police Station.:

Date: Time:

(b) General Diary Reference:

Entry No.: Date and Time:

4. Type of Information:

5. Complainant/ Informant:

- (a) Name:
 (b) Father's/ Husband's Name:
 (c) Date/ Year of Birth:
 (d) Nationality:
 (e) UID No.:
 (f) Passport No.:
 Date of Issue: Place of Issue:
 (g) ID Details (Ration Card, Voter ID Card, Passport, UID No., Driving License, PAN)

S. No.	ID Type	ID Number

(h) Occupation:

(i) Address:

S. No.	Name	Address

(j) Phone no.:

Mobile:

6. Details of known / suspected / unknown accused with full particulars:
 Accused more than:

S. No.	Name	Relative's Name	Present Address

7.

S. No.	Property Category	Property Type	Particulars of properties of interest	Value (in INR)

8. Total value of property (in INR):

9. Inquest Report / U.D. case No., if any:

S. No.	UIDB Number

10. First Information contents:

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