GENERATING INSIGHTS FROM CORRELATING DRIVING BEHAVIOR OF DRIVERS WITH THE CHANGING DRIVING CONTEXT

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ABSTRACT

India has one of the highest rates of road accidents in the world. In 2016, the total number of road accidents, both reported and unreported, was estimated at more than 5 million. With such high mortality and morbidity rates, the need for urgent remediation becomes imperative.

Government of India publications clearly report driver fault as the primary cause of road accidents and fatalities. In fact, rash driving behavior in challenging contexts, is known to severely impact trip quality, undermine passenger/driver safety and can even lead to fatal accidents. Yet, driving behavior, in isolation, may not sufficiently explain the incidence of road accidents, but when analyzed along with the driving context, provides deep insights on safe driving.

Driver behavior is strongly influenced by the surrounding driving context, which impacts the driving response quality of an individual driver to a sudden emerging situation. Imagine a standardized system that provides following insights on driving behavior of a driver: 'Driver A / NH4 / full truck load / 70+ kmph / 01:00-04:00 AM /aggressive tailgating / banked road with sharp curve / speed humps'. Such reporting provides a detailed understanding of the interaction between Driver A and his overall driving context.

Driving context and driver response can be correlated to better understand his/her overall driving behavior, which is a collection of thousands of manifestations of the driver's driving profile. These profiles provide valuable insights about the driving behavior of an individual driver, and highlight those drive-situations where the driver is more likely to have an accident.

ROAD ACCIDENTS: A PERSPECTIVE ON INDIAN ROADS

India has one of the highest rates of road accidents in the world. In 2015, the total number of road accidents was more than 500,000, with a growth of 2.5% over the previous year. But the number of fatalities due to road accidents grew by more than 4.5% (over the previous year) while the number of accidental injuries increased by 1.4% (over the previous year). The annual increase in fatality rate was much higher than the overall accident rate, implying a significant increase in the severity of road accidents.

TABLE 1 Road Accident Parameters (2014 and 2015)

Parameters	2014	2015	% Change over Previous Year
Total Accidents in the country	4,89,400	5,01,423	2.5
Total number of Persons Killed in the country	1,39,671	1,46,133	4.6
Total number of Persons Injured in	4,93,474	5,00,279	1.4

Parameters	2014	2015	% Change over Previous Year
the country			
Accident Severity*	28.5	29.1	2.1
* *No. of persons per 100 accidents*			
The total number of road accidents per lakh increased in the country			

TABLE 2 Number of Road Accidents and Persons Affected (2005 - 2015)

Year	Number of Accidents		Number of Persons		Accident Severity
	Total	Fatal	Killed	Injured	
2005	4,39,255	83491 (19)	94,968	465,282	21.6
2006	4,60,920	93917 (20.4)	105,749	496,481	22.9
2007	4,79,216	1,01,161 (21.1)	114,444	513,340	23.9
2008	4,84,704	1,06,591 (22)	119,860	523,193	24.7
2009	4,86,384	1,10,993 (22.8)	125,660	515,458	25.8
2010	4,99,628	1,19,558 (23.9)	134,513	527,512	26.9
2011	4,97,686	1,21,618 (24.4)	1,42,485	5,11,394	28.6
2012	4,90,383	1,23,093 (25.1)	1,38,258	5,09,667	28.2
2013	4,86,476	1,22,589 (25.2)	1,37,572	4,94,893	28.3
2014	4,89,400	1,25,828 (25.7)	1,39,671	4,93,474	28.5
2015	5,01,423	1,31,726 (26.3)	1,46,133	5,00,279	29.1

Table 2 shows the last 10-year data on road accidents and their impact, in terms of fatalities and injuries.

The Government of India data for the period 2005 -2015, on road accidents only reinforces the fact that the rate of road accidents have increased continuously over the years, with the growth rate of fatalities being significantly more pronounced than the overall increase in the road accident rate. In addition, while the rate of road accidents has increased by 14.2%, the rate of associated fatalities has shown an increase of 53.9%, and the accidental injuries have increased by 7.5%. In 2015, the Fatality Rate from road accidents was at 1 death per 3.4 accidents, indicating an alarming increase in the severity of road accidents.

While there is a steady increase in the rate of road accidents, the rate of increase in severity of accidents is much higher, leading to significantly higher proportion of fatalities as compared to the overall road accident rate; this is a serious cause of concern for all stakeholders, due to its long-term implications.

As a signatory to the Brasilia Agreement, India is committed to reduce the number of fatalities arising from road accidents by 50%, but this is possible only if the government works in a planned manner. The Government of India publications clearly implicate the driver as the singular cause of road accidents and the associated fatalities and injuries. As per statistical data for 2015, driver faults alone account for more than 77% of road accidents as well as 72.6% of deaths and 80.3% of injuries.

But this is perhaps half the picture. A driver's driving behavior varies with the road condition, geographical terrain, environmental conditions, etc. in which he is driving. As can be seen from Table 3, various other factors, besides "Driver Fault" have been listed as the driving cause of

road accidents. Some such conditions include factors such as defects in vehicle condition, difficult weather conditions, poor road conditions, stray animals etc.

But as the primary objective of any forensic analysis of a road accident is to identify the principal cause of accident, the high-risk factor is identified as the causal factor for the accident, which in most cases is the Driver Fault. Most of the "other" causes are attributed to a very small proportion of road accidents, while primarily indicting the driver in majority of cases. But it is incorrect to indict individual drivers as the sole cause of road accidents, without considering the impact of poor driving conditions on driver response to the context leading to the accident.

TABLE 3 Accidents Classified According to Causes (2015)

Causes	Accidents		Killed		Injured	
	Number	**%**	**Number**	**%**	**Number**	**%**
Fault of Driver	3,86,481	77.1	1,06,021	72.6	4,01,756	80.3
Fault of Cyclist	3,695	0.7	1,384	1	2,928	0.6
Fault of Driver of other vehicles	24,431	4.9	6,961	4.8	19,686	3.9
Fault of Pedestrian	7,509	1.5	2,690	1.8	5,962	1.2
Defect in Condition of Motor Vehicle	11,601	2.3	4,127	2.8	9,818	2
Defect in Road Condition	7,314	1.5	2,733	1.9	6,122	1.2
Weather Condition	5,781	1.2	2,552	1.7	4,792	1
Fault of Passenger	6,668	1.3	2,657	1.8	6,265	1.2
Poor light	5,456	1.1	2,095	1.4	4,809	1
Falling of boulders	1,087	0.2	505	0.3	966	0.2
Neglect of civic bodies	1,076	0.2	416	0.3	902	0.2
Stray animals	1,534	0.3	579	0.4	2,044	0.4
Other causes/ Causes not known	38,790	7.7	13,413	9.2	34,229	6.8
Total	**5,01,423**	**100**	**1,46,133**	**100**	**5,00,279**	**100**

Rash driving behavior in challenging contexts, is typically the outcome of driver's response to poor driving conditions (road condition, terrain, traffic, etc.), which in turn severely impacts trip quality, undermines passenger/driver safety and in extreme cases, may lead to fatal accidents.

Thus, driving behavior, in isolation, may not sufficiently explain the incidence of road accidents. For instance, a driver driving at a speed of 60 kmph may be the cause of accidental injury in a specific set of driving conditions (say, city driving in low to moderate traffic) but can be classified as "safe driver" in a different set of road conditions (driving on well-maintained National Highway).

Hence it is important to analyze driving behavior in the context of the prevailing driving conditions to get real insights with respect to driving behavior of individual drivers.

PUTTING DRIVING BEHAVIOR INTO PERSPECTIVE

Driving behavior of an individual driver can be defined as the premeditated or natural response of a driver to a given driving context. Driving context is not fixed, it changes continuously with the driver's journey. A driver's response is expected to be commensurate to the relevant driving context, to ensure an accident free journey. Hence understanding driving context is critical for ensuring correct assessment of driving behavior of an individual driver or to identify the root cause of rash driving behavior. Driving behavior, in fact, is strongly influenced by the driving context, which in turn impacts the quality of driving response of an individual driver to a sudden emerging situation.

The driving context depends on: road design and engineering, quality of road maintenance, type of road, road surface (concrete/asphalt), individual vehicle type (commercial or passenger, HCV/MCV/LCV vs Sedan/Hatchback, Truck vs Bus, carrying load or empty, etc.), surrounding traffic conditions (heavy vs light, mixed traffic or singular), city driving vs highway driving, instantaneous weather conditions (visibility, rain, wind, heat), night vs day driving, driving during office hours or otherwise, and a host of other factors. (For more details, refer Figure 1).

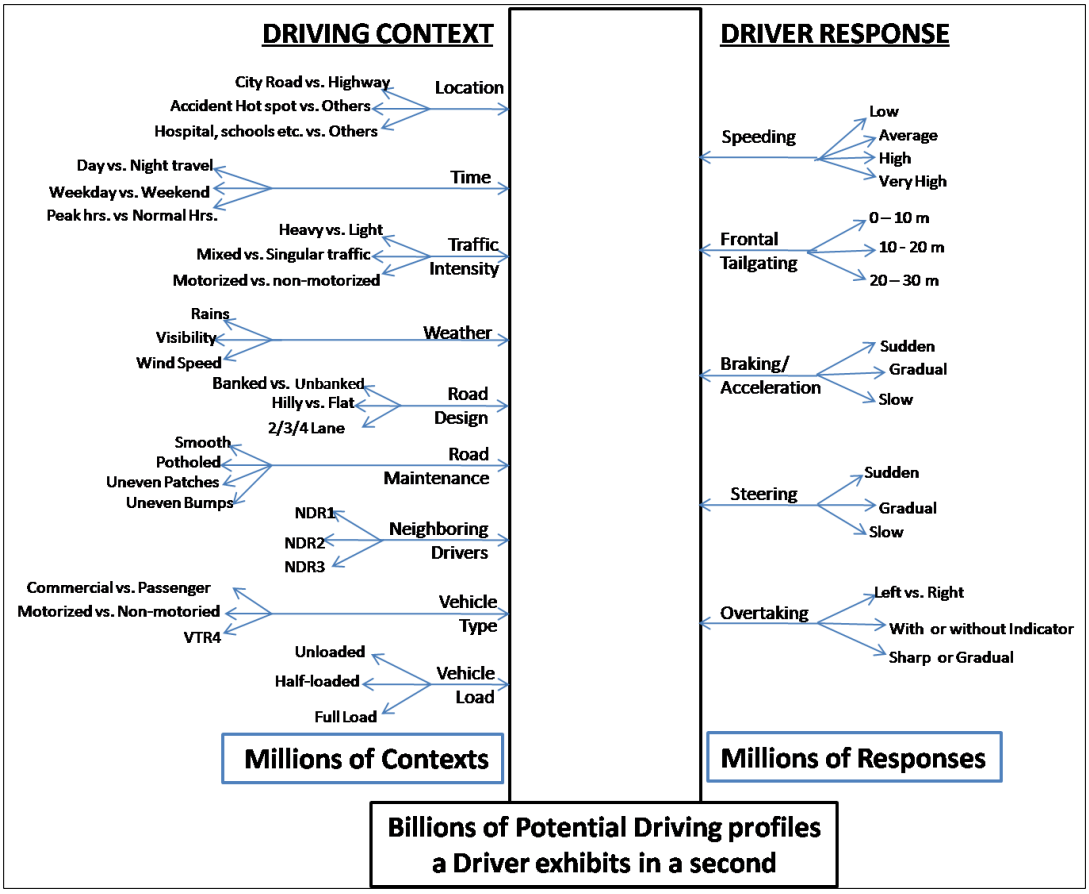

FIGURE 1 Driving Context vs Driving Response

A driving context, is in fact, a combination of multiple context and demands/elicits a response specific to the context. A driver response not commensurate with the specific context can lead to an incident/accident with fatal/non-fatal outcomes.

Driving Behaviour: By Road Type

Let us consider the example of **"Road Type"** as a driving context.

In India, roads can be classified into 3 major categories – National Highways, State Highways and Other Roads (urban/rural roads). An analysis of the accident rate of the three categories of roads reveals clear insights on driving behavior across the three Road Types.

Table 4 shows the percentage share of National Highways, State Highways and Other Roads in Total Road Accidents, Persons Killed and Injured for 10 years for the period 2005 -2015.

TABLE 4 Percentage Share of various Road Types in Total Road Accidents, Persons Killed

Year	National Highways			State Highways			Other Roads		
	Road Accidents	Persons Killed	Persons Injured	Road Accidents	Persons Killed	Persons Injured	Road Accidents	Persons Killed	Persons Injured
2005	29.6	37.3	31.3	23.6	27.2	25.7	46.8	35.5	43
2006	30.4	37.7	30.8	18.5	26.8	24.9	51.1	35.5	44.3
2007	29.0	35.5	30.2	24.4	27.7	26.2	46.6	36.8	43.6
2008	28.5	35.6	28.6	25.6	28.4	27.5	45.9	36	43.9
2009	29.3	36.0	29.6	23.8	27.1	25.5	46.9	36.9	44.9
2010	30.0	36.1	31.3	24.5	27.3	26.0	45.5	36.6	42.7
2011	30.1	37.1	30.5	24.6	27.4	26.1	45.3	35.5	43.4
2012	29.1	35.3	30.1	24.2	27.3	25.9	46.7	37.4	44.0
2013	28.1	33.2	28.9	25.6	29.6	27.6	46.3	37.2	43.5
2014	28.2	34.1	29.9	25.2	29.1	26.8	46.6	36.8	43.3
2015	28.4	35.0	29.1	24.0	28.0	26.3	47.6	37.0	44.6

A preliminary analysis of Table 4 data shows that the accident rate for "Other Roads" categories is significantly higher than that for National Highways and State Highways. An empirical analysis of accident data for "Other Roads" reveals that most of the roads with high accident rates include rural roads which are either kuchha roads or poorly maintained roads, leading to high accident rates. Thus, it may be concluded that poor road infrastructure is the primary cause of high accident rate in rural areas.

In comparison, State and National highways, which are considerably better maintained and have lower traffic congestion, have significantly lower accident rates, implying that there is significantly high of correlation between Type of Roads and driving behavior of individual drivers.

Driving Behavior: By Road Category

A further analysis of road category – **"Urban and Rural Roads"** and their influence on the driving behavior of individual drivers can be can be seen from the Table 5, that compares road accident rate with road infrastructure type - rural or urban.

TABLE 5 Total Accidents, Persons Killed and Injured in Rural & Urban Areas (2015)

Category	Fatal Accidents		Total Accidents		Persons Killed		Persons Injured	
	#	%	#	%	#	%	#	%
Urban Area	50,959	(38.7)	2,31,894	(46.2)	56,978	(39)	2,04,545	(40.9)
Rural Area	80,767	(61.3)	2,69,529	(53.8)	89,155	(61)	2,95,734	(59.1)
Total	**1,31,726**	**(100)**	**5,01,423**	**(100)**	**1,46,133**	**(100)**	**5,00,279**	**(100)**
Note: Figures in parentheses indicate share of the total.								

The data from Table 5 shows that the proportion of road accidents in rural areas is significantly higher than that in the urban areas. In fact, the table further reveals that the mortality and morbidity rates from accidents on rural roads far exceeds that of the urban roads.

As the quality of road infrastructure in the rural areas is considerably poorer than that in urban areas, it results in much higher accident rates as well as significantly higher proportion of persons killed or injured during the accidents. Thus, quantitative data clearly indicates that quality of road infrastructure strongly influences the driving behavior of drivers.

Driving Behavior: By Time of Driving

Similarly, another important driving context is the "**Time of Driving**", Analysis of accident rates across various "times of the day" reveals interesting insights as shown in Table 6.

TABLE 6 Road Accidents by the Time of Occurrence (2015)

Time	Day / Night	Number of Accidents	% Share in total Accidents
06:00:00 - 09:00:00 hrs	Day	55,518	11.1
09:00:00 - 12:00:00 hrs	Day	81,964	16.3
12:00:00 - 15:00:00 hrs	Day	79,616	15.9
15:00:00 - 18:00:00 hrs	Day	87,819	17.5
18:00:00 - 21:00:00 hrs	Night	86,836	17.3
21:00:00 - 24:00:00 hrs	Night	51,425	10.3
00:00:00 - 03:00:00 hrs	Night	27,954	5.6
03:00:00 - 06:00:00 hrs	Night	30,291	6.0
Total 24 hrs		5,01,423	100

An analysis of road accidents' data for the year 2015 reveals that unlike common perception, that most accidents take place late into the night, due to poor light conditions and driver fatigue, in actual case, accident rates are the highest in the late afternoon (3:00 pm - 6:00 pm), followed by early evenings (6:00 pm – 9:00 pm).

In fact, data from Table reveals that accident rates are much lower during late night and early morning hours, which in turn can be explained by the cautionary/safe driving behavior exhibited by drivers, along with lesser traffic congestion which improves the quality of the driving context.

Thus, from the Table 6 data, it may be safely concluded that deviant driving behavior is not influenced by the amount of lighting on the roads or driver fatigue alone. In fact, high accident rates during late afternoons and early evenings can be co-related with several other contextual factors.

For instance, higher traffic congestion on roads (office goers in a rush to go home) and rash driving behavior of fellow vehicle drivers, during early evenings, may influence driving behavior of individual drivers, leading to severe impact on road safety and higher accident rates.

Similarly, during late afternoons, increased traffic congestion, due to greater number of school transportation vehicles plying on the roads, along with post-lunch fatigue of drivers (lower alertness levels) may be responsible for higher accident rates among drivers.

Driving Behavior: By Type of Road Junctions

Safe driving behavior of drivers also depends on the type of "**Road Junctions"** that they navigate during travel and whether these junctions are monitored or unmonitored.

For instance, an analysis of location of road accidents for the year 2015, as shown in Table 7 reveals that T-junctions have the highest rate of road accidents, more than 38%, followed by Y-junctions, about 20%. In comparison, Round About Junctions have an accident rate of about 5% only.

Also, contrary to popular belief that railway crossings have one of the highest accident rates, data for the year 2015 shows that the Unmanned Railway Crossings account for just 2.1% in a year, implying thereby that driving behavior of drivers is also influenced by the risk perception of driving locations. Hence many such high-risk locations have been classified as Accident Black Spots, with the objective to alert the driver to exercise safe driving behavior while navigating them.

TABLE 7 Total Number of Accidents, Persons Killed & Injured based on Type of Road Junction (2015)

Type of Junction/ Crossing	Accident		Killed		Injured	
	#	%	#	%	#	%
T-Junction	94,487	38.5	24,441	38	91,366	38
Y-Junction	48,776	19.8	12,371	19.2	45,292	18.8
Four arm Junction	40,430	16.5	10,469	16.3	40,258	16.7
Staggered Junction	26,491	10.8	7,232	11.2	25,151	10.4
Junction with > 4 arms	15,439	6.3	4,035	6.3	19,288	8
Round about Junction	13,276	5.4	3,725	5.8	11,577	4.8
Manned Rail Crossing	1,552	0.6	584	0.9	1,479	0.6
Unmanned Rail Crossing	5,215	2.1	1,503	2.3	6,006	2.5

Driving Behavior: By Weather

Another critical factor that influences driving response is the prevailing **"Weather Condition"**. A commonly held perception is that accident rate is high during monsoon/ rainy season. But

quantitative analysis of driving behavior, as shown in Table 8, negates the perception completely.

TABLE 8 Month-Wise Classification of Accidents – Impact of Weather on Driving Behaviour (2015)

Month	Accidents	Killed	Injured
January	42,661	11,922	43,169
February	40,661	11,599	40,307
March	42,842	12,651	43,108
April	42,432	12,740	43,173
May	46,247	14,354	47,224
June	42,065	12,490	41,721
July	39,694	11,049	39,430
August	39,126	10,776	39,177
September	39,761	11,101	39,355
October	42,089	12,097	41,689
November	41,018	12,323	40,413
December	42,827	13,031	41,513
Total	**5,01,423**	**1,46,133**	**5,00,279**

Analysis of Monthly Accident Rate reveals that road accident rates are the lowest in the monsoon season (July, August, September), indicating a practice of safe driving behavior being exercised by drivers in adverse weather conditions. Thus, it may be said that there is a direct correlation between risk perception of a driving context and the commensurate response of drivers to the adverse driving conditions.

Thus, a detailed analysis of road accident data under different context, clearly indicates varying response of drivers to changing driving context. But each such data reflects a specific driving context in isolation, for e.g. accident rate on highways vs. other roads, rural roads vs. urban roads, time of the day etc.

However, in real life, a driving context does not exist in isolation and hence such singular data may not reveal enough information about the driving behavior of individual drivers. At the same time, empirical analysis of the data indicates that each driving context is a collage of multiple driving context and consequently elicits a unique response from each driver.

UNDERSTANDING DRIVING BEHAVIOR

Despite varying driving contexts, and their corresponding influence on driving behavior, a singular perception of a driver usually gets formed. For example, analysis of road accident data reveals much higher accident rates on rural roads in comparison to urban roads. Such an analysis has the risk of labeling a driver as a poor navigator of rural roads vs urban roads. In fact, based on the above analysis, a fleet operator may develop an impression that “Driver A drives rashly on rural roads” or “Driver B doesn’t know city driving”, etc.

But such a generalized analysis is insufficient to create a complete skill profile of the concerned driver and hence does not create right opportunities for skill improvement. In fact a general analysis of a driver's driving behavior creates a singular perception of his driving behavior that does not consider various other factors that could influence the response of the driver to the given context.

For instance, in the case of Driver A, the perception that he cannot navigate rural roads efficiently, does not consider the influence of other contexts prevalent during his trip. The assessment of Driver A does not consider factors such as the congestion on the road, time of driving, type of vehicle, whether the vehicle is loaded/ unloaded, does the Driver A navigate through multiple black spots on the route, is the route under supervision of traffic police / police and several other factors. In this case, however, knowledge of location of black spot could elicit safer driving response from Driver A. Similarly, existence of traffic police/ police personnel on key junctions could lead to safer driving behavior from other vehicle drivers and hence a better driving behavior from Driver A.

Similarly, for Driver B, there is no data available on the maintenance condition of the city roads on his route, the design of speed breakers, whether the traffic junctions are monitored/ unmonitored, traffic congestion on the route during his driving hours etc.

For instance, it is likely that very heavy traffic along with poor driving behavior by other drivers on the route could elicit rash driving response from Driver B in a specific stretch. However, Driver B, while navigating through junctions monitored by traffic police/ police, could exhibit safe driving behavior.

Now let us imagine an automated and standardized system that provides following insights on driving behavior: 'Driver B /NH4 /full truckload /70+ kmph / 01:00-04:00 AM /aggressive tailgating /banked road with sharp curve /speed humps'. Such reporting provides a detailed analysis of Driver B's driving behavior for the specific part of the trip, where he exhibits rash driving behavior. In addition, the system also provides detailed insights on the driving context for the trip, which helps one assess the exact driving risk profile of Driver B for the trip.

Thus, in contrast to building a generalized perception of the driver, the fleet operator or the driver himself can pinpoint the exact area of concern with respect to his driving behavior. A Driving Risk Score Card for the trip can further quantify the risk profile of the driver, which can act as a serious deterrent for the driver from indulging in similar behavior in a high risk driving context in the future, in turn providing a specific and much better understanding of the impact of the overall driving context on the driving response of Driver B.

DRIVING RISK FOR EACH MANIFESTATION OF DRIVING PROFILE

The above analysis clearly establishes that driving behavior is not exhibited in isolation. It is in fact the behavioral response of a driver to a given driving context. In fact, driving context when correlated with driver response, provides a better understanding of the driving behavior of individual drivers.

But driving context is not an isolated environmental context. In fact, any real-life driving context is a combination of multiple contexts and therefore elicits a specific response type, commensurate with the risk profile of the given driving context.

Thus, driving behavior of a driver is, in effect, a collection of thousands of manifestations of the driver's driving profile, in line with the given driving context. These driving profiles provide valuable insights about the driving risk profile of each driver for the given driving context.

An in-depth analysis of the numerous driving profiles of an individual driver provides deep insights about his overall driving risk profile. In addition, the numerous driving profile manifestations of a driver, especially w.r.t. to the complex driving context, also highlight those driving situations where the given driver is more likely to have an accident. Such detailed driving risk profile of individual drivers can be of immense benefit for fleet operators and drivers.

A detailed assessment of drivers for high risk driving behaviors can form the basis for tailored interventions for each driver, which will not only improve their overall driving behavior, but also assure a safe ride to their customers.

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