Study of Techno-Legal Aspects of Accident Site Investigation—A Case Study from Bengaluru

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Abstract After a major road crash, conducting crash investigation is generally the next step. But the road accident spot analysis is not carried out as per the procedure in most of the road crashes in India. Although crash spot studies are conducted by associated officers, the procedure, implementation, and post-investigation studies are charge framed, nontechnical, and not available in the public domain. The study aims to investigate the techno-legal aspect of the crash site investigation of a typical crash from Bengaluru which occurred between the motorbike and the car. Crash spot was studied, analysis of accident spot parameters, and vehicles inspection observations are correlated and used to infer the reason for the crash. This article aims to highlight the importance of scientific investigation of the road accident site and the sequence of activities happening after the occurrence of the road accident with a case study.

Keywords Urbanization · Motorization · Road accidents · Crash investigation · Legal aspects

1 Introduction

Crashes and fatalities on the road are the results of the interplay of several factors. Road users in India are heterogeneous with standard and nonstandard vehicles and drivers. Motor vehicle collisions cause more than 1.35 million deaths worldwide and an even greater number of non-fatal injuries each year [1]. As reported in [2], road traffic is a major issue and is a leading cause of death worldwide. The data released by the Ministry of Road Transport and Highways has highlighted road crashes to

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be one of the biggest causes of unnatural deaths occurring in India. Developing countries account for 90% of these casualties. In India, the pace of development of the vehicle population is quicker than the economic and population growth. The surge in motorization coupled with an expansion of the road network has increased road crashes. Almost 1.5 lakh people in India lose their lives due to road crashes annually, and India accounts for nearly 11% of the road accident-related deaths in the world [3]. According to statistics released by the Karnataka state police, the number of persons who lost their lives due to road crashes in Bengaluru rose by 82 in 2019 with 768 deaths compared to 686 such deaths reported in 2018. The increasing number of road fatalities is a matter of concern, and it is essential to focus on road safety. At the same, most road crash cases are resolved by the case in-charge officer without highlighting the fundamental problem of road crashes, technical aspects and how to overcome the same. Most of the crash case reports is prepared by victimizing larger/insured vehicle than the real issue in the particular crash. Similarly, very limited technical studies of road crash spot analysis are reported in India finding out the real cause of the crash. Even though crash can be due to: (1) improper infrastructure (road surface, gradient and signs boards), (2) signaling, (3) faulty vehicles, and (4) driver behavior. All other aspects can be overridden if driver is intelligent and follows proper traffic rules. Most of the road crash reports only on vehicle or driver factors, which are investigated nontechnically and the driver behavior of the larger vehicle is quickly blamed as rash driving/negligence as it is difficult to prove both without any video records. So, in this study, we carried out a detailed analysis of road accident with technical aspects and explained how legal, technical aspects help determine the actual problem of crashes based on a typical road accident case in Bengaluru. This paper also aimed to understand the techno-legal aspects of road accident site investigation. It provided a detailed study with an example of how can an ordinary person collect data and effectively handle legal aspects to prove/disprove charges prepared nontechnically. Nontechnical reports are prepared in most of India's road accident cases by nonexperts and never reviewed or corrected by technical experts.

2 Literature Review

The detailed, objective investigation of the causes and mechanisms of injuries in traffic crashes originated in the United States. Mackay et al. [4] illustrated a fundamental problem of field accident investigation. The importance of the need of going to the accident scene within a few minutes of the occurrence of the accident and collecting every bit of information available and its analysis to provide a better insight into the causes of injury is discussed.

There is no theoretically underpinned framework for collecting and analyzing accident-related data in the road transport domain, which is universally accepted. The application of use systems theory-based human factors accident analysis methodologies is problematic for various reasons, including incompatible data collection procedures, a lack of detail in the following data collected, a lack of theoretically

underpinned analysis methods, and a lack of appropriately trained personnel. Paul and Michael [5] discussed the barriers preventing valid, reliable, and usable accident analysis within the road transport domain and, in closing, present a series of proposed solutions to the barriers discussed.

England [6] has described and evaluated Accident Investigation as a method of producing information to reduce the frequency of road accidents. Here the detailed investigation is done, looking both at the road user's interaction with the road environment and within the environment itself. The problem of a road accident and possible approaches to accident reduction is introduced, and the importance of the multidisciplinary approach to the second-level in-depth investigation of the accident to determine countermeasures is discussed. Hill et al. [7] considered detailed investigations focusing on all types of vehicles (including damage, failures, features fitted, and their contribution); the highway (including design, features, maintenance, and condition); the human factors (including drivers, riders, passengers, and pedestrians); and the injuries sustained for the study of new 'On-The-Spot' (OTS) accident research project which is now underway in the UK.

An in-depth database will permit analyses to better understand the causes of crashes and injuries and assist in the development of solutions, which is the main objective of this paper. Baldock et al. [8] focus on studying factors that contribute to road crashes, with an emphasis on the role of road infrastructure. The methodology of carrying out the detailed investigation of the crash scene is discussed in detail, and also the key road safety problems that need to be addressed are identified.

Mackay [9] has attempted to outline some of the benefits which might be obtained from a more thorough and comprehensive examination of transport, and particularly road traffic and accident. From the thorough investigation of the road accidents, detailed evidence which exactly explains the circumstances of a particular collision may be produced and also provides the car designer, traffic engineers and other concerned authorities with practical results to take up the right remedial measures.

Evans [10] raises ethical issues relating to drivers, industry, and government regarding the death in traffic accidents. Increased professional and public discussion of the ethical issues surrounding all causes of harm in traffic can make a major contribution to reducing this harm.

In short, very limited research papers are available on the crash investigation of the accident pinpointing the faulty driver/vehicle. The above papers describe the importance of carrying out the detailed investigation of the crash, and going to the crash spot within few hours of the occurrence of the crash which gives a better understanding of the crashes. It also states that there is no standard theoretical framework to carryout the crash investigation and this study comprises the framework of road crash investigation which can be used for understanding the techno legal aspects and issues involved in crashes.

3 Study Site and Information About Road Accident and Sequence of Events

In this study, a classical known crash case that occurred in Bengaluru has been taken for analysis. Even though crash is common to any two moving entities on the road, four- wheelers and two-wheelers are very common and frequent victim vehicles in developing countries like India. In this study, collision is between (four-wheelers) car and (two-wheelers) motorbike in the urban area. The crash spot with nearby location and origin spot of both vehicles before the crash is shown in Fig. 1. The motorbike coming from the Bio-Chemistry building collided with the car on its left side, which was going toward D-Gate of IISc Campus. Figure 2 shows the location of the accident spot with the direction of both the vehicles and the exact location of the collision. The car driver immediately applied the brake, and the car stopped. By the time bike went under the car (on the left side of the car), causing heavy damage to the car bumper, radiator, A/C components, oil pumps and associated spare parts in the left front of the car and also the bottom up to the left middle of the car. The driver of the two-wheeler was not wearing a helmet, and the bike indicator was off. The car had leakage of oil and water from the coolant and suffered damage due to the heavy impact of the bike. Bike was found below the car and had damages on the left side of the bike such as bumper and petrol tank, and headlight was intact. Further, both vehicles were moved away from the spot and the bike driver had injuries on the left hand, he walked to an ambulance and was sent to treatment at a nearby Health Center. Subsequently, the car was moved to the side of the road, and the car driver

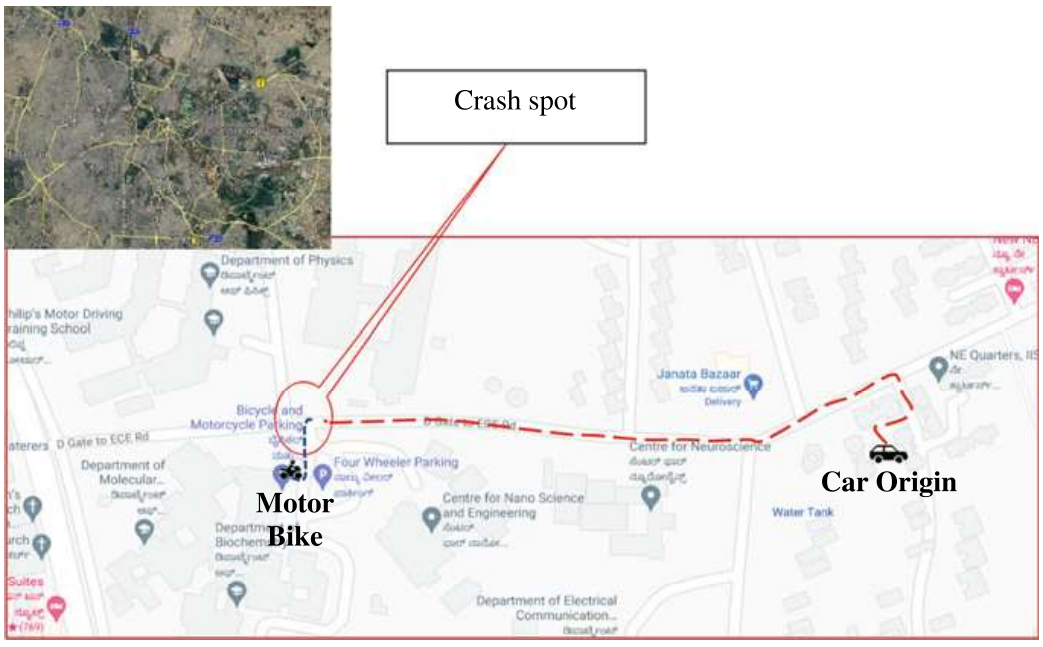

Fig. 1 IISc map showing the car moving path and the crash location (Figure prepared using Google Maps)

Fig. 2 Show view of the road from car direction (toward D-gate) with blind zone at the left of car due to fencing vegetation

left the crash spot. Later bike was moved to the parking area. Car was inspected by authorized service engineer and he suggested to move the car through tow vehicle and after few hours the car was towed to the nearest service station. Vehicle travel distance from origin spot is shown in Fig. 1, and it can be seen that car had crossed four junctions and about 270 m after the last junction point (Janatha Bazaar Circle). The bike just had one turn and approached, reaching gate and road junction after passing a steep-sloped ramp.

The marked portion of the road from Janatha Bazaar Circle to the entrance of the Centre for Nano Science and Engineering is having an upward grade. In this case, rising speed in a short duration (less than 300 m) is technically not feasible and reduces the possibility of rash driving. When a vehicle moves from Janatha Bazaar Circle toward D Gate, the left of the car is a blind zone due to dense vegetation and fencing. Figure 2 shows a photo of the blind zone close to the crash spot. As bike has to claim a steep slope (see Fig. 3a) before reaching gate and road, the bike might raise acceleration to claim the slope. The total incident was reported to the security office as the incident happened in the closed gate community. Since bike driver looks like a student and car driver being faculty, no police complaint was filed about the incident.

However, later it was found that the bike driver who does not belong to the campus had filed a case against the car driver at the police station in different sections. The car driver visited the station and explained the situation with evidence that he has not made any mistake and it was a mistake of the bike driver. However, the police did not register any complaint and asked the car driver to inform the court, but took few signatures in the document written in the local language, which was not known

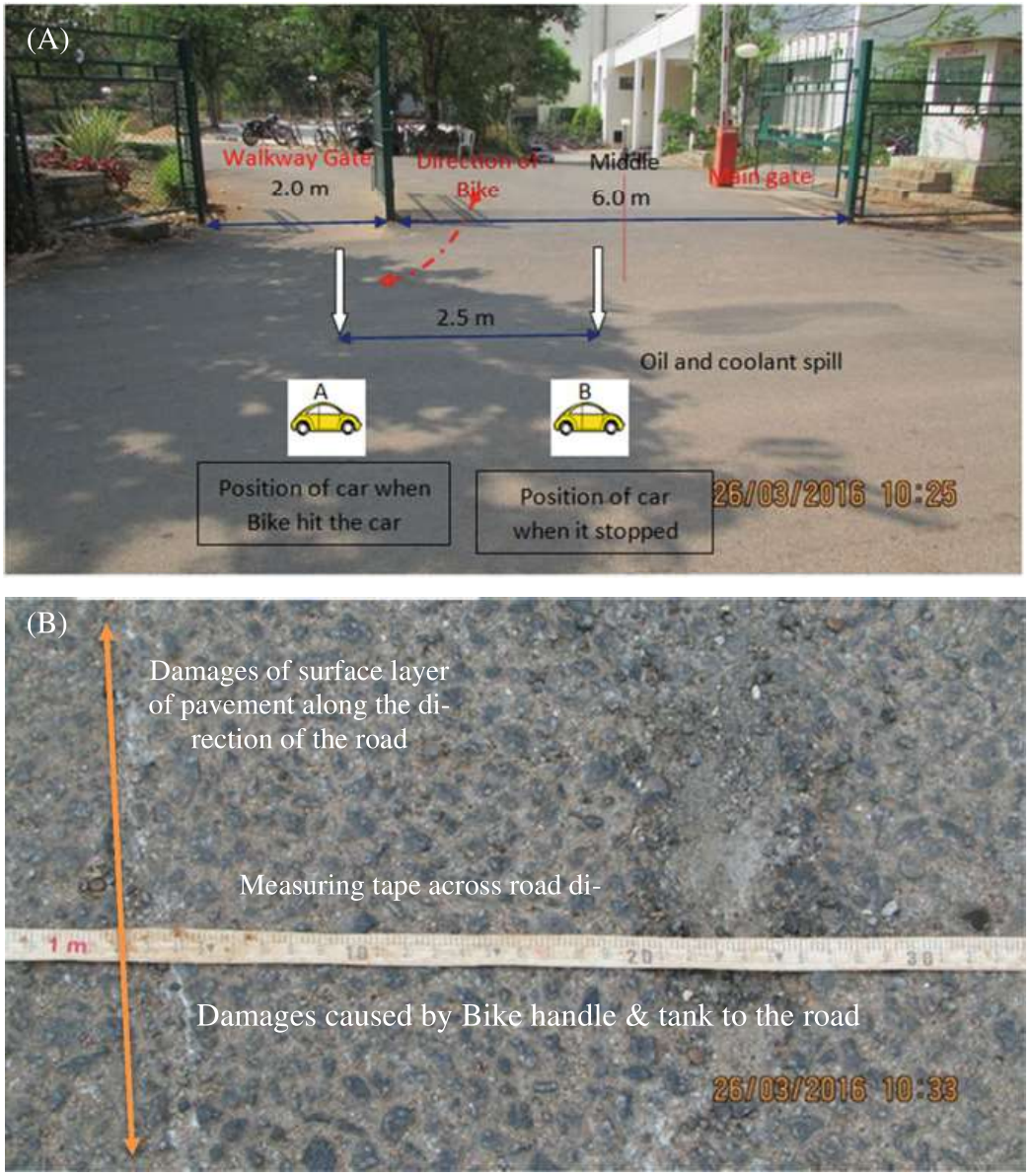

Fig. 3 **a** Crash spot with the marking of the initial position of the car at the time when the bike hit the car, final position where the car was stopped, gates and stopping distance marking and oil spill on the road. **b** Closer view of structural damage of road due to hitting bike handles and distance from the edge of the road (the left side toward D-Gate)

to the car driver. As car driver and owner were not happy with the police behavior, they asked the IISc team to study the accident and prepare a factual report.

4 Investigation of Road Accident Location

The authors personally visited the site and tried to understand the crash in technical detail before concluding the crash. The crash spot was studied, and data collected from the site are compiled to prepare the schematic location and vehicle position. Figure 3a shows the crash spot with information collected from the geometrical parameters. It was found that car was moving on the left side of the main road, and the bike was coming from the approach road to the main road. Crash spot was studied, and ground evidence was collected like soil, coolant spill location, and road damages caused by vehicles. The total width of the main road is 6.4 m, and damages on the road due to bike handle and tank hitting bitumen surface (Fig. 3b shows road damage with measurement) was noticed within 1.2 m from the left edge of the road. It indicates that during and after the crash, both vehicles are within the left lane of the main road. By tracing the beginning to end line of road damage along the left lane point of the road damage, we could arrive at the distance traveled by both vehicles after collision (initial damage location by bike handle) up to the halt position (final position where oil and coolant spill starting point and end of handle damage in the road). The bike left handle created an impression in the bituminous road surface up to 3.8 m followed by a patch mark on the road surface due to leakage of oil and coolant, which is the endpoint of the crash. Figure 3a shows the photos of road with bike handle impression, walkway gate, and main gate with oil and coolant spill on the road surface. Initial position at the time of the crash and the final position of the car after stopping are marked in Fig. 3a as A and B; we measured the distance between these two points as 3.8 m along the main road and 1.2 m from the left edge of the main road. Other geometric data are collected and marked in the crash spot photo in Fig. 3a. The position and direction of vehicles at the time of the crash and after both vehicles were halted were mapped. It can be clearly noted that there is a violation of traffic rules by bike driver, instead of exiting at the left lane of the approach road; bike exited at the right lane of the approach road, which is a violation of traffic as per Indian Traffic rules.

By carefully studying crash spot and road marks, the following conclusions can be drawn.

- The crash occurred about 1.2 m from the left edge of the main road in the left lane toward D Gate.
- Both car and bike were in motion at the time of the collision, which happened in front of the walkway in the left lane toward D gate fencing.
- After falling, the bike's left handle caused structural damage to a road opposite to walkway entry.
- No car wheel impression on the main road was observed, which mean that car has not applied sudden brake in high-speed.

Based on the above points, it is very clear that the two wheelers were in the right lane of the side road and turned right into the left lane, i.e., left side of the car rather than turning from the right side of the car.

The two-wheeler parking area entry and exit in approach road were also studied, and a Google Maps is shown in Fig. 4. Considering blind spot for a vehicle toward D Gate, the campus had separate parking and exit for two-wheelers as shown in Fig. 4.

Considering parking for two-wheelers and exit location, it is very clear that the bike should have come out on the main road from the dedicated exit gate for a two-wheeler to avoid blind spot and 90° turning at approach road in Fig. 3b.

As explained above and also as per the crash location marking, the bike was taking a right turn in the left lane towards the main road instead of taking a safe exit gate, which may be due to the bike driver is not familiar with campus and these traffic regulations, as he is not campus user or resident. Figure 5 presents the condition and

Fig. 4 Crash spot in Google Maps with entry and exit arrangement made as per traffic rules

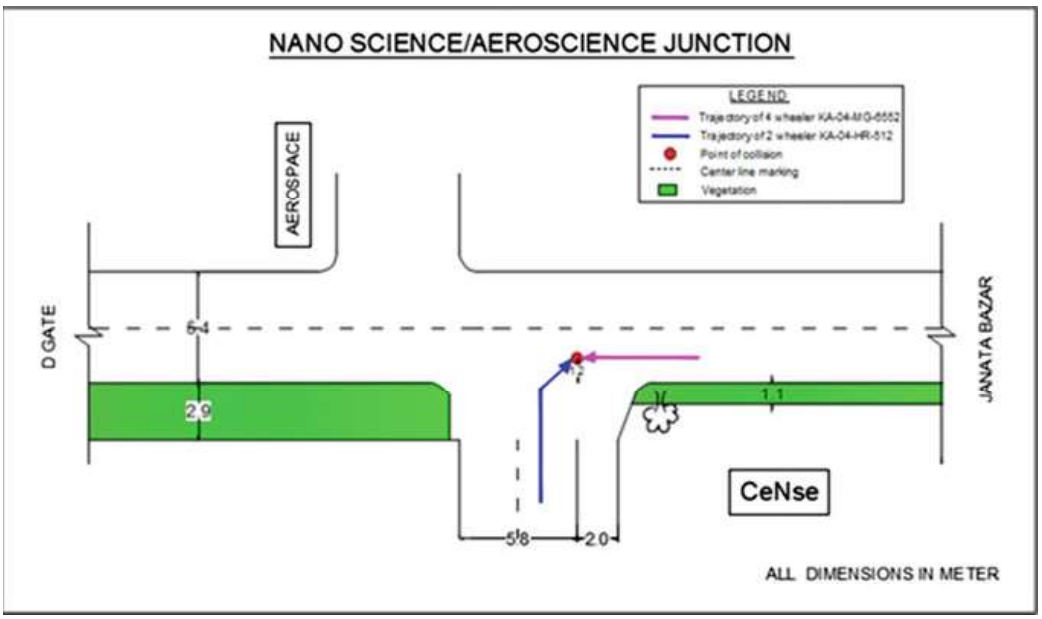

Fig. 5 Condition and collision diagram of the crash location

collision diagram of the crash prepared to explain the same after sufficient evidence and study discussed above.

Further, bike was entering the main road from the approach road and should ideally stop and watch on both sides of main road for a safe gap before proceeding further as per driving rules, the priority for movement goes to the vehicles on the main road, however, the bike was in motion at the time of the crash. As there was no car wheel impression on the road observed in photographs, it is plausible to assume that the car had stopped after normal breaking in the normal speed. Generally, the wheel impression of a vehicle is created on the road during accidents when applying sudden brake at high speed (for example, more than 60 km/h). Since the car stopped at 3.8 m from the initial point of the accident, it indicates that the car driver applied a brake on time, and car was stopped within the driver's reaction time, which is further explained later.

5 Investigation of Vehicles

As part of the crash investigation, vehicle damages should be studied apart from the geometric study of crash spots. Hence, the authors inspected both vehicles after the crash, took photos, and collected service reports of vehicles. Figure 6 shows typical photos of the bike taken during the inspection. The bike's right side, back, and front side are intact; no damages are noticed. The bike had damages in the left side, i.e., Bummer folded, headlight cover, and left-side handle damage and petrol tank left-side damage. No car paint or impression is noticed on any part of the bike, and no service report was available from the bike owner or in the case document.

Similarly, car was inspected at the service station as car was towed to the service station as per the service inspection report of the authorized car service station. We

Fig. 6 Typical photos of bike after the accident, parked within campus

have taken several photos and also collected on spot service report with recommendation and service station inspection and estimate. Figure 7 shows typical photos taken during the inspection. Quick visual observation of the car gives the impression that car was not damaged much, except for few scratches and dents (Fig. 7a) in the front between the number plate and left side of a car headlight. We also noticed the bike tyre impression next to the number plate. It indicates that bike hit a car in a straight and opposite direction of car driving direction. Further interaction with car driver and owner, service person and study of on-spot service report, we deepen our inspection. Figure 7b shows oil spill at a service station parked location similar to the oil spill marking in Fig. 3b. After seeing an oil spill, inspection shows the damage of car bumper, radiator, A/C components, oil pumps, and associated spare parts in the left front of the car and the bottom up to the left middle of the car. The photo was taken by placing a camera after lifting of damaged bumper and shown in Figs. 7c. Now, it is clear that damage of a major portion of radiator and front units results in car's non-operation driving status, which is why it was suggested to tow vehicle by inspection report. A study of the estimation of the service station revealed that replacement of most of the above spare parts of car was estimated to be Rs. 51,393.

By studying both vehicle photos, the following inferences were made.

- The bike's left handle bar damages were noticed due to the pavement surface, which is also confirmed as pavement damage reported in Sect. 4 of the accident location study.
- Other damages, scratches, and dent in the bike may be caused by bike interaction with the pavement surface. No evidence was found to say car hit the bike as the right side and front part of bike is intact.

- Bike wheel mark impression on car bumper and associated scratches, dent in Fig. 7a shows that bike hit the car. Further, car bumper was broken and damages in the major front assemblies of the car such as radiator, A/C components, and oil pumps (Fig. 7b) were observed. This clearly shows that the bike might have hit the car with higher acceleration than car i.e., speed of the bike might be more than the speed of the car.
- Bike damages on the left side indicate that after colliding with the car the bike fell on the left side, which caused damage to the left side of the bike and not on the right side, which is evident from structural damage to the main road.
- We can also infer that when a car hits a bike in a stopped position, the right side of the bike should be damaged, but in this case, the right side of the bike is intact and no damages are seen from Fig. 6. We can infer that the bike was also in motion at the time of the collision which hit the car, lost balance, turned left side, and moved under the car. So the left side of bike got damaged after hitting car on the main road and caused structural damages to the pavement surface.
- Figure 7 shows clearly that the number plate and left headlight of car (Fig. 7a) is intact after the collision. In general, when the car hits another vehicle like bike, the front portion of car such as the front number plate and head light will get damaged. In the present case, since the number plate of the car is intact and the

Fig. 7 Photos of car after the crash taken at the service station. **a** Car front with number plate, scratches and bike wheel impression created. **b** Oil and coolant leakage at the parked location and **c** damaged car radiator and A/C unit not visible outside

damages are on the left side of the bike, it suggests that the bike hit the car toward its left, i.e., between car number plate and headlight, which is possible only if bike hit the car and not when car hit the bike. Further, the bike was attempting to enter the main road toward the left of the car, which should ideally be from the right side. Bike should be damaged if car hit the bike, but it was not so.

- Figure 7c shows damages of radiator assembly and other parts of the car. Bigger damage impression on the radiator might be created by the impact of bike front wheel as the handle impression will be small. This suggests that the bike hit a car while in motion with a speed force that is above the design strength of the car radiator front panel.

6 Analysis of Geometric Data

After the study of crash spot and vehicles, we could come up with some inferences, but mostly qualitative and not quantitative parameters. Hence, available data collected are further studied and used to arrive at quantitative results helpful to support the qualitative hypothesis. The braking distance of the vehicle is the distance between the initial position of the car at the point where the impact happened and the final position of car after stopping by applying the brake.

In this study, structural damage to the road (impression and mark in Fig. 3a) caused by a bike can be taken as the initial point of crash, and the origin of oil and coolant leakage can be taken as the final vehicle position, i.e., halt of vehicles after the crash. Location of car after the crash, i.e., stopped position also confirmed with driver of car and eye witness on the spot, i.e., security person. There is no video recording in this location of the campus. Physical measurement in the accident spot of the initial and final position of the car was measured and found to be 3.8 m, as shown in Fig. 3a. The stopping distance or distance within a motor vehicle can be a function of (a) total reaction time of the driver, (b) speed of vehicle, (c) efficiency of brakes, (d) frictional resistance between the road, and (e) the tyres and gradient of the road. In this case, we have a stopping distance measurement of 3.8 m, which can be used to estimate the speed of the vehicle, and other parameters can be taken based on the accident spot. Indian Road Congress highlighted that the total reaction time of a good driver is 2.5 s. Based on this, the speed of car (km/h) can be calculated by the formula given below as per Khanna and Justo [11].

$$V = \sqrt{254 d \mu}$$

The speed of any vehicle (V in km/h) is a function of d = braking distance (m), which is 3.8 m in the present case, and μ = coefficient of friction (unitless). The friction of the accident road is assessed as per the Indian Road Congress Guidelines and varies from 0.4 to 0.35 depending on speed from 30 to 80 km/h. Variation of the possible speed of car based on 3.8 m stopping distance by variation of coefficient of friction is shown in Fig. 8. It can be noted from the analysis that car speed might be

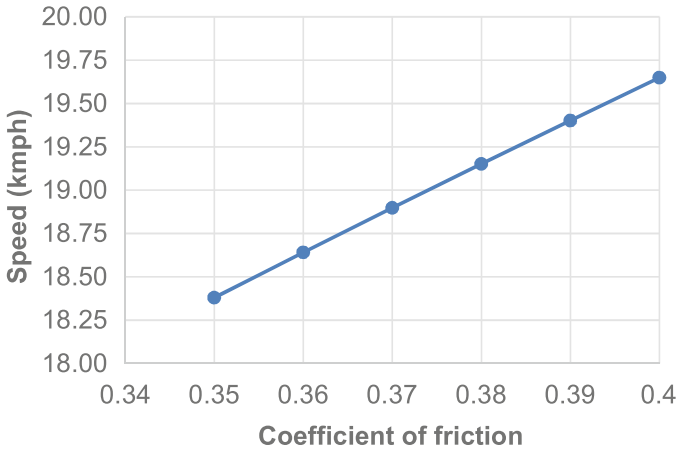

Fig. 8 Variation of car speed involved in the accident for the various coefficients of friction of the road

18 to 20 kmph. Even if maximum speed is taken, the estimated speed at the time of the accident is found to be 20 km/h, which is less than the speed limit of 30 km/h on the roads in campus and Bangalore city speed limit of 60 km/h. So, there is less chance that car might have caused accident.

7 Summary and Conclusion

Several accidents have occurred in different parts of India, but most accident are never technically studied and understood. In this study, for the first time, a detailed crash investigation was carried out for an accident between four-wheelers and two-wheelers. Analysis of accident spot parameters and vehicles inspection observations are correlated and used to infer the reason for the accident. Further, data collected from the accident spot was used to estimate the speed of one of the vehicles involved in the accident. Even though traffic rules violations and the speed of the bike caused the accident, but the cases of hit and run, over speed was booked against the car driver and owner despite sufficient evidence and data to the police. After about six months of the accident, the car owner and driver received court notice and then underwent court proceedings and procedures but did not accept police charges. After nearly two years, car driver and lawyer finally proved that all charges made by police, documents, and eyewitnesses were not correct by providing some evidence discussed in this paper without any eyewitness and cleared all charges. In summary, this paper highlights the importance and value of scientific accident site investigation and use it to conclude legal issues arising out of road accidents.

This study is based on one case study of the road crash. More case studies in different locations and different situations can be analyzed using a similar framework to understand the general applications of the proposed framework and also the framework can be modified to make it a more generalized framework in all the situations of road crashes.

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