CLINICAL RESEARCH

Environmental Factors of Commuting Accidents among Firefighter Drivers in Peninsular Malaysia: A Case study

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ABSTRACT

Introduction	Commuting accidents (CAs) caused significant detrimental impacts on the Fire and Rescue Department of Malaysia (FRDM). Therefore, this study aims to identify factors of CA by mainly focusing on environmental factors
Methodology	The qualitative data was obtained from FRDM accident investigation reports from five states (Kedah, Selangor, Kuala Lumpur, Negeri Sembilan and Johor) between 2017-2021. The data were analysed using content analysis.
Results	Four environmental factors that contribute to CA were identified. The factors were environmental conditions (rainfall, strong wind, light glare, and insufficient lighting), time (twilight and night time), road physical conditions (hilly road, curvy, steep, and narrow road, weak manhole cover, soft ground, wet and slippery road), and road environment (traffic congestion and sudden animal crossing)
Conclusion	These findings provide environment-related hazards input for risk assessment and management of CA in FRDM, as well as valuable information for future research. Therefore, it has the potential to improve road safety for firefighters, the general public, and animals.
Keywords	Commuting accident - environmental factor - firefighter.

Article history:
Received: 2 February 2023
Accepted: 29 August 2023
Published: 1 September 2023

INTRODUCTION

Road traffic accidents (RTA) are a major worldwide public health concern as they killed about a 1.3million each year.[1] This concern was also raised in Malaysia, as the trend increased by 3% from 2018 to 2019, which was 567,516 cases.[2] Similarly, this issue is faced by the firefighter population not only globally but also in Malaysia, with an average of 50 accident cases per year.[3,4] In relation to this work-related RTA study, commuting accident (CA) among firefighter is defined as any contact of firefighter vehicle with an object (e.g., motor vehicle, roadside barrier, object on or off the roadway, pedestrian, cyclist, or animal), either moving or fixed, at any speed during journey which directly connected to work. Statistically, CAs in the Fire and Rescue Department of Malaysia (FRDM) cause a detrimental impact in terms of health (12% of the cases injured and 1.2% died), finances (4.5 million MYR lost), and services (retardation of fire and rescue service operations due to adverse effects to the drivers from CA event and asset damages) within 2016-2021.[3] Focusing on CA related to environmental factors, the estimated cost lost from the five highest accident states (Kedah, Selangor, Kuala Lumpur, Negeri Sembilan and Johor) was RM 272,000.[3]

The occurrence of CA is known to be a result of interaction between human, vehicle, and environmental factors. Among these factors, the human factor plays a major contributor, such as aberrant driving behaviours, unfavourable functional fitness level and health condition.[5] However, CAs due to environmental factors such as bad weather, poor road lighting, surface and geometry as well as unexpected animal cross should not ignored. They also contribute to the likelihood of road accident which could cause detrimental impacts not only to firefighters but to public road users and the environment.[6–10] Despite its negative consequences, environmental factors of CA among firefighters rarely explored. Therefore, this paper aims to identify environmental factors of CA among the firefighter population.

METHODOLOGY

Background

This study was based on data obtained from FRDM accident investigation reports of five states in Peninsular Malaysia that had high CA cases, which are Kedah, Selangor, Kuala Lumpur, Negeri Sembilan, and Johor between 2017-2021. A total of 93 CA cases (Table 1) with different types of accidents (Figure 1) were reported. Only 65 reports in which the cause of the accident was conclusively determined were selected in this study. Subsequently, CA cases that were attributed to environmental factors by investigators review were extracted.

Table 1 Number of firefighters commuting accident cases by states (2017-2021)

State / Year	Kedah	Selangor	Kuala Lumpur	Negeri Sembilan	Johor
2017	5	7	1	3	5
2018	1	7	1	3	2
2019	6	11	3	6	2
2020	3	9	5	3	1
2021	6	1	1	1	0
Total	21	35	11	16	10

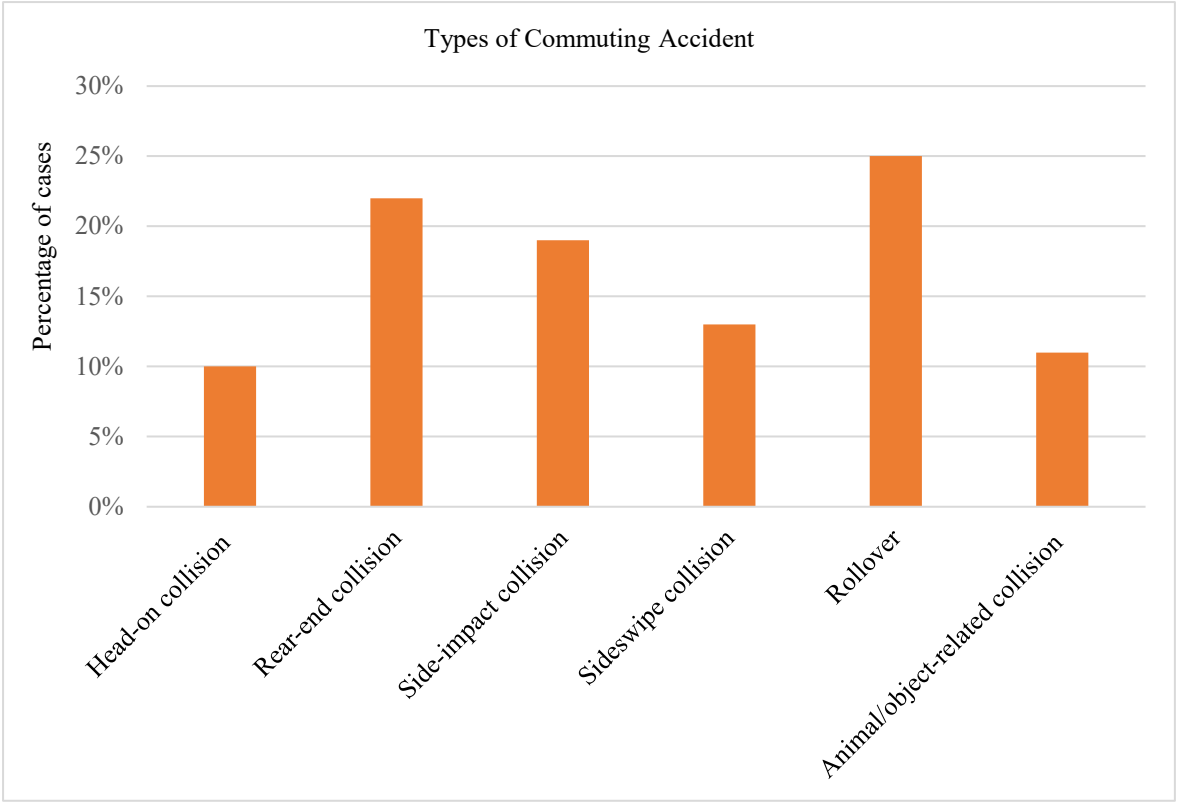

Figure 1 Type of commuting accidents in the fire and rescue department 2017-2021

Data analysis

The inductive content analysis in this study was performed following three phases that proposed by Elo and Kyngas.[11] The three phases are preparation, organising, and reporting (Figure 2). In the preparation phase, an overall understanding and familiarisation of the qualitative data were established through repeated reading of the report sections and contents. Then, the units of analysis were selected, namely the interview transcription of case and accident witnesses, as well as summary of accident causes by accident investigators. Subsequently the key statement of environment-related accident factor was highlighted. The next step in the content analysis process is the organising phase. In this phase, the qualitative data were organised through open coding, categorising, and abstracting. In open coding, notes were written in text during line by line review. After that, the extracted related words and phrases were pooled in a group and classified into sub-categories. Sub-categories with similar incidents were grouped under generic categories and eventually main categories/themes were created.

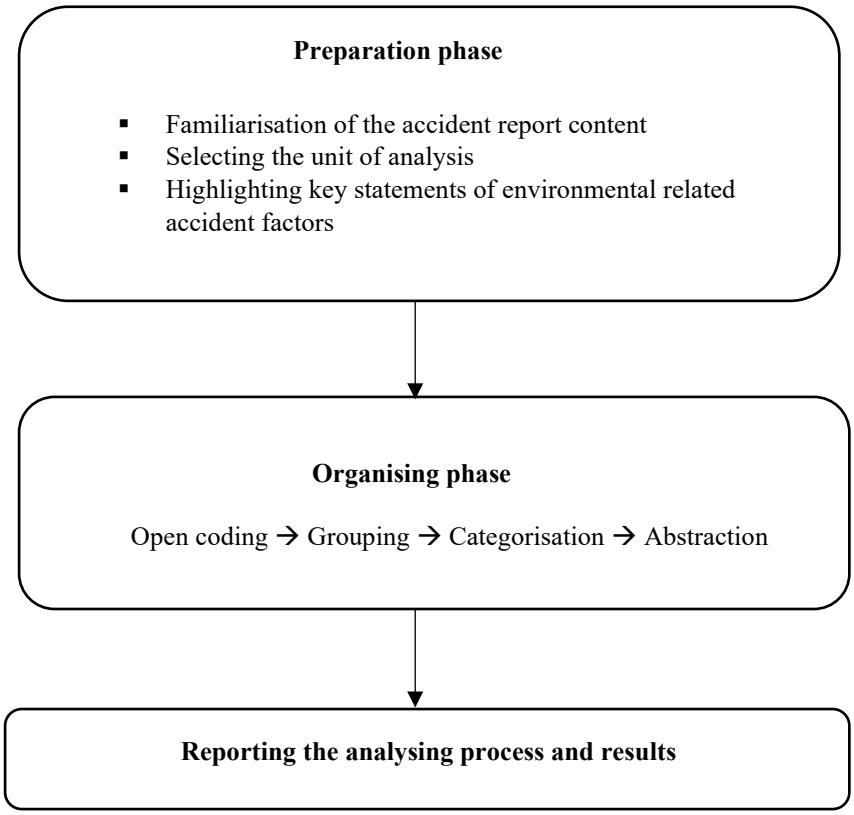

Figure 2 Content analysis process

Taking into consideration data transferability, sentences and categories were extracted using accident investigation findings as they were. In addition, inductive content analysis results were revised multiple times in order to ensure dependability and confirmability.

There was a total of 65 accident investigation reports reviewed and 27 (41.5%) of them were influenced by environmental factors. As a result of inductive content analysis, four main categories were identified as environmental factors that contribute to CA which were environmental conditions, time, road conditions, and road environment. Table 2 shows the results of the data abstraction process.

RESULTS

Table 2 Results of the data abstraction process

Sub-category	Generic category	Main category
Heavy rain	Weather	Environmental conditions
Rain		
Drizzle		
Strong wind		
Light glare	Light conditions	
Dark road		
Poor road light		
Twilight	Times of the day	Time
Night time		
Hilly road	Road topography	Road physical conditions
Curve road	Road geometry	
Steep road		
Narrow road		
Poor quality of manhole cover	Road detail	
Soft ground	Soil instability	
Wet road	Road surface conditions	

Slippery road		
Road congestion	Road traffic	Road environment
Collision with animal	Animal crossing	

Environmental Factors

Environmental condition

70% (19 cases) of CA cases were due to environmental condition, in which 58% (11 cases) associated with bad weather and 42% (8 cases) was associated with light condition factors. Exposure to unfavourable environmental conditions of bad weather and poor light conditions were reported in CA cases. Rainy weather was reported in nine accident cases as it caused low visibility as well as wet and slippery roads. Other than that, heavy rain with strong wind was also noted to be indirect cause of CA. In one case, these weathers caused three electric poles to topple and resulting in collisions with Fire Rescue Tender (FRT).

Refer to poor light conditions, dark roads (6 cases) and poor road light (1 case) result in poor visibility causing collision with roadside objects, which were electric cables, garbage bins, and tree stumps. The CA was further influenced when the driver drove on a non-routine road. Another accident causation reported was glare from the headlights of the vehicle (1 case). The glare reduced the driver's visibility, causing fail to manoeuvre the Fire Rapid Vehicle (FRV) to avoid hitting a sudden cow crossing.

Time

14.8% (4 cases) CA reported to occur during the early evening (1 case) and night time (3 cases). It was due to poor lighting during this time and reduced driver visibility. Accident risk was further increased when there was also an object or animal on the road, driving on a narrow road, and glare from the vehicle.

Road physical condition

78% (21 cases) of CA cases were due to road condition factors. 10% (2 cases) occurred at hilly road, 24% (5 cases) curve and steep roads, 28% (6 cases) narrow road, 5% (1 case) weak manhole cover, 5% (1 case) soft foundation soils, and 28% (6 cases) wet and slippery road. All CAs caused by road factors occurred among large and heavy fire vehicles. For example, accidents at hilly narrow roads occurred among FRT, bus, and lorry. Driving on a hilly road associated with CA because of the steepness and the topography cause limited visibility for drivers to front view. A weak manhole covers also became a problem for FRT as it was unable to support FRT weight, which eventually broke and caused the FRT tyre to be tucked in the hole.

Road environment

Road environment factors contribute to 22% (6) of CA cases. Factors were traffic congestion (4 cases) and collision with animal (2 cases).

DISCUSSION

Environmental factors of CA among firefighter drivers can be divided into four main categories, which are environmental conditions, time of day, road physical conditions, and road environment.

In terms of environmental conditions, weather and light conditions play role in accident causation. Bad weather such as rainfall reduced visibility of the firefighter drivers and reduced road friction. Besides, it can also impair driving performance.[12] A case study from Mexico revealed a significant relationship between accident occurrence and bad weather (OR 5.56).[13] Similarly, various studies in the later period also reported rainy weather resulting in road accidents.[14,15] Furthermore, the wind also affects road safety. The association between wind effect and accidents has been reported in previous studies.[6,16] Wind blows can affect vehicle stability and control during moving and reduces drivers' sight due to road debris circulating upward.[7,17] In regard to the firefighter CA case, a strong wind had an indirect cause of an accident where it caused the collapse of a roadside object and caused a collision with the fire vehicle.

Refer to light conditions problem, dark roads and poor roads light results in CAs among firefighter drivers. Due to these factors, they had a collision with objects adjacent to the lane. Dark and poor road light are known to cause limited visibility, poor visual judgment and the possibility of distraction, reducing attention and sleepiness.[18] There are multiple studies have reported increasing accident risk due to poor lighting.[8,19] Referring to firefighter accidents, these factors were also influenced by other sub-category elements which were rainfall, and curvy and narrow roads. Apart from that, glare from the headlights of an oncoming vehicle was also contribute to CA causation in this study. It is because, glare reduce the visual performance of drivers as it lessen the image contrast in retina.[20] Previous literature reported that glare is a principal factor of hazards on the road.[21]

Additionally, time of day is also one of the environmental factors related with CA in firefighter. In this study, CAs that occurred at twilight and night time were found concurrent with limited visibility, poor road light, curvy and narrow roads, rainfall and sudden animal crossings. Many studies discovered that road accidents were prone to happen at night.[22,23] It might occur due to driver fatigue and sleepiness as well as over speeding because of fewer vehicles on the road at night time.[22,23] A study on

fatigue-related crashes showed 20.8% of the accident occurred from midnight to dawn (12 am to 6.59 am), and fatigue was about three times (OR = 2.72) likely occurred from midnight to dawn.[23]

Further, road physical conditions of hilly road, risky road geometry, poor quality of manhole cover and unstable soil condition were found to influence CAs among firefighters. Hilly region is considered prone to accident location because they are usually characterised by risky road geometry, such as steep, curved, and narrow road, which can lead to physical and mental fatigue and limit the driver's visibility. Limited visibility in hill regions can also be due to the combined effect of bad weather, such as rain and fog.[9] Referring to firefighter drivers, the road geometry of the hill poses challenges for them to manoeuvre the large fire truck. Based on the reported case, the CA was also influenced by the darkness condition.

Other sub-categories for road conditions are curvy, sloped, and narrow roads. In curved and slope roads, there is a possibility of vehicles deviating from their current route due to inappropriate vehicle handling, speeding, and understeering.[24] Meanwhile, on a narrow road, the accident frequency is high because sharing lanes with other vehicles increases the risk of collision.[25] In firefighters, the possibility of accidents is higher, especially when driving a fire truck. Due to it high level and heavy characteristics, drivers need to have good skill in manoeuvring the braking system to get appropriate speed to reduce truck instability during driving on this risky road geometry. Another factor that needs to be considered is the water momentum impact from the tank in the fire truck, where the water surge can cause speed increases and instability.

Apart from that, a poor quality of manhole covers on roads exposes hazards to road users, especially among heavy vehicles drivers.[26] One accident case of FRT was due to tuck into a manhole while driving on it. Further investigation revealed the material used to make the manhole cover was not sturdy to support heavy FRT.

Other than that, soil instability also holds a risk of road accidents. One firefighter lorry accident case was due to the collapse of unstable ground, which eventually skidded and fell into the drainage. Issues on the association of road hazards with unstable soil are also reported in a few literature.[27,28] This problem will get worse in the presence of repeated rainfall and heavy vehicle passing on the road.[28]

Finally, sub-categories for road environment causing road accidents are traffic congestion and animal crossing. The previous study showed an association between traffic congestion and road accident, but the findings were mixed. It speculated that traffic congestion may pose road safety benefits because of low averages speed during that event.[29] Nevertheless, the latest study showed a significant high correlation (0.81) between traffic congestion and road accident.[30] It might be due to high traffic volume and aberrant driving behaviour of drivers between lanes during congestion[29]. Referring to firefighter drivers increases traffic volume poses a risk to them, especially those who drive fire trucks. Driving a large vehicle with a wide blind spot area on a congested road will increase the possibility of hitting motor vehicles around them.

Other than that, the sudden animal crossing caused CAs among firefighters. One of the accident cases was also associated with other factors, which were disability glare and rainfall. In Malaysia, 341 cases of animal and vehicles collision were reported between 2010-2020.[10] Referring to firefighter CA cases, the collision occurred with a wild boar and cow. Meanwhile, in the general population, the highest animal-vehicle collisions in Malaysia were with cows and pigs.[10]

CONCLUSION

Current case study result showed environmental factors of CA among firefighters are environmental conditions (rainfall, strong wind, light glare, and insufficient lighting), time (twilight and night time), road physical conditions (hilly road, curvy, steep, and narrow road, weak manhole cover, soft ground, wet and slippery road), and road environment (traffic congestion and sudden animal crossing). However, this study found that most commuting accidents result from the interaction between a few sub-factors instead of a single cause. Even though CAs due to environmental factors contribute less than 50%, the accident did not merely threaten the traffic safety of firefighter drivers but also public road users and the environment. Furthermore, CAs have always been costly as involves FRDM high-cost asset (fire vehicles). Hence, findings from this study provides environment-related hazards input for risk assessment of CAs in Malaysia fire departments. Subsequently, intervention for risk control can be planned holistically, including policy (e.g., redesigning existing policy to improve fire vehicle safety by using vehicle banksman and improve driver safety through annual fitness to drive assessment) and engineering approaches, such as installation of backup cameras, proximity sensors especially in large fire vehicles, to prevent backing incidents and usage of safety reflectors. In addition, training and education can be improved by emphasising vehicle control techniques during inclement weather, poor illumination, road geometry and topography, and education on avoiding animal collisions. Furthermore, it is crucial that the educational session integrates statistical data concerning fire vehicle accidents associated with the environment factor. This data should be disseminated to all FRDM drivers, alongside a specified time for drivers to share their own

experiences with accidents. This approach aims to enhance driver awareness and promote a safer driving environment. As importantly, future research is needed to determine the effect of environmental factors on CAs in the firefighter driver population.

ACKNOWLEDGEMENTS

The authors would like to express our appreciation to the Fire and Rescue Department of Malaysia for approving accident cases data usage.

Ethical considerations

The study on commuting accidents in firefighters was approved by the Research and Ethics Committee, *Universiti Kebangsaan Malaysia* (UKM PPI/111/8/JEP-2022-424). Permission on accident investigation report data usage was obtained from the Fire and Rescue Department of Malaysia (reference number: JBPM/IP/OPS: 600-7 (24)).

Competing Interests

The authors declare that there is no conflict of interest.

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