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A SYSTEMS-BASED APPROACH TO DEEPLY EXAMINE A DOWNGRADE-TRUCK CRASH CAUSED BY A BRAKE FAILURE IN VIETNAM

Do Duy Dinh[a,*], Vu Hoai Nam[a]

[a]*Faculty of Bridge and Road Engineering, Hanoi University of Civil Engineering, 55 Giai Phong road, Hai Ba Trung district, Hanoi, Vietnam*

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Abstract

Truck crashes related to brake failure have been an increasing issue for traffic safety in Vietnam recently. Although previous studies have pointed out several variables directly related to this type of crash, there has been no research to further examine influencing factors resulting from other actors representing inside a road transport system and the interactions among them. A systems-based approach, enabling the analysis of the influence of various actors within the road transport system, was used in this study to elucidate the contributing factors to a road traffic crash involving a truck traveling downhill apparently caused by a brake failure, on a mountain highway in Vietnam. The results indicated that apart from the direct factors leading to the accident including the driver's inexperience, the vehicle's low quality, and severe road conditions, other actors at upper levels of the Vietnamese road transport system also had indirect effects on the collision. On the basis of the aforementioned findings, the implications for safety interventions and related policies were also discussed.

Keywords: traffic safety; downgrade truck collision; sociotechnical systems; accimap; road transport system.

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1. Introduction

Downgrade truck crash, where a goods vehicle traveling downhill collides with other vehicles or infrastructure, is commonly caused by a brake failure and often leads to serious damage to lives and property. Vietnam is a country with an extensive network of mountainous roads, therefore the traffic safety issue from this type of crash has been attracting increasing attention. Although there have been no exact statistics on the rate of deaths related to downgrade truck collisions in Vietnam available, this traffic accident problem has been highly highlighted in the Vietnamese media recently. For example, at least five people were killed and two others were injured after a truck experienced a brake failure and then collided with other vehicles on National Road No.20 in the central highlands province of Lam Dong on May 14th, 2018 [1]. On September 15th, 2018 in the northern mountainous province of Lai Chau, a concrete mixer truck lost control when traveling downhill, and crashed into a passenger coach, leading to 13 deaths and three seriously injured casualties [2]. These are just two recent illustrations of a common issue that demands attention, in a nation that saw more than 8000 deaths caused by traffic crashes in 2017 [3, 4]. It should be noted that there have been no previous studies focusing on examining the influencing factors in this type of accident or solving these types of problems in Vietnam. Based on police investigations' results, the causes of most downgrade truck crashes in Vietnam were often related to drivers and/or vehicles' characteristics.

Trucks' loss of control is highly pertaining to downgrading truck crashes and plays a significant role in truck crashes in general. As reported in the Large Truck Collision Causation Study (LTCCS),

*Corresponding author. *E-mail address:* dinhdd@huce.edu.vn (Dinh, D. D.)

loss of control accounted for 28.6% of truck crashes [5]. Previous research has revealed that the risks of these types of crashes were commonly higher on steep downgrades as compared to other typical road sections [6]. In addition, the combination of severe grade and sharp curvature is a significant contributor to the problem [7]. Downgrade truck crashes have been found to be affected by various variables in which drivers' inexperience in downhill driving, defective brakes, and inadequate signing were identified as the main causes of these collisions [8]. The environment and highway geometry have been also revealed as contributory factors as well [6]. Although various factors of downgrade truck collisions have been explored and a number of traffic safety measures have been proposed and applied based on the existing findings, the issues of downgrade truck collisions still exist [9]. As aforementioned, past research has mostly focused on the immediate, proximal causes of downgrade truck crashes. There has been very little attention paid to higher socio-technical factors that form road transport systems from which these types of collisions arise. It could be argued that the downgrade truck crashes might potentially arise from other factors residing at upper levels of the system as well as the interactions amongst them. Tracing the main causes of downgrade truck collisions by using this different approach could expectedly obtain effective measures to address the serious traffic safety

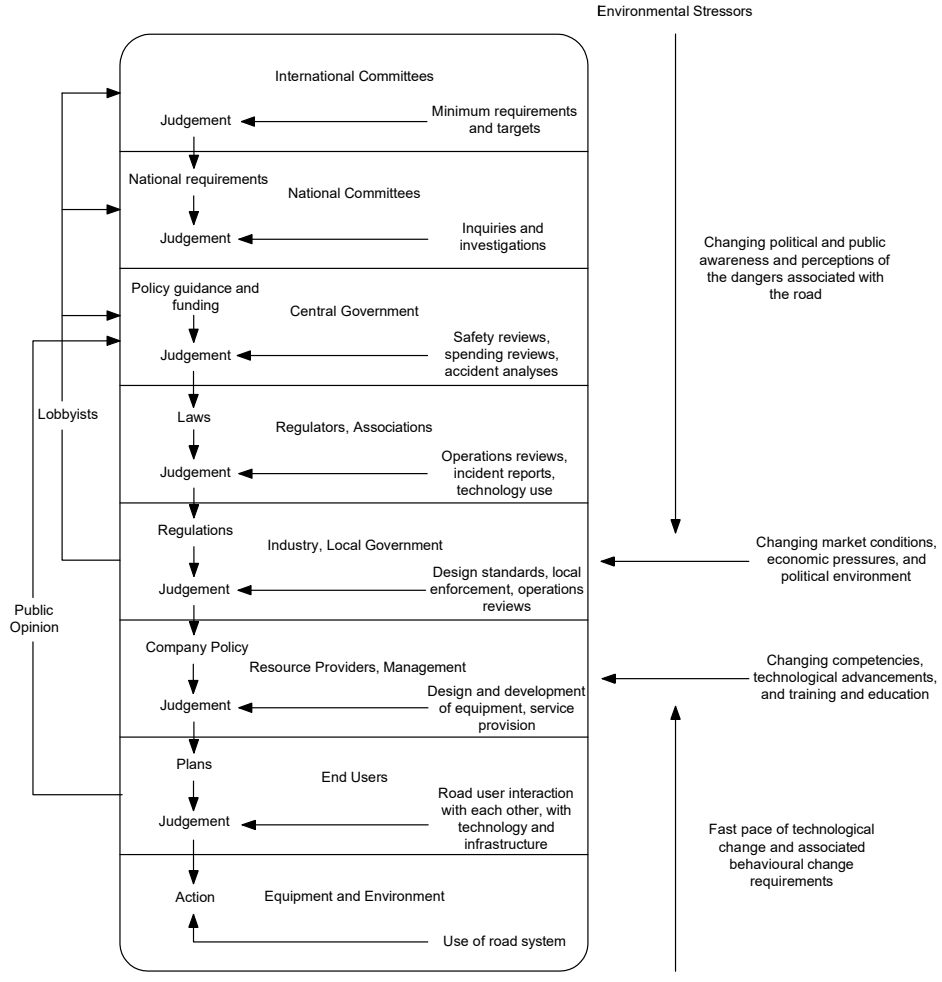

Figure 1. An expanded version of Rasmussen's Risk Management Framework (RMF), modified by Parnell et al. [16] and McIlroy et al. [17]

issue in Vietnam, as well as in other low- and middle-income countries with similar settings. A sociotechnical systems-based approach, a philosophy that has recently gained increasing attention in road safety research, is a potential alternative to finding out the causes of road traffic crashes. This approach is based on a guiding principle in which safety is an emergent property arising from nonlinear interactions between a system's components [10]. To make it easier on examining accidents in complex sociotechnical systems, Rasmussen's risk management framework [11] has been used across a variety of domains, including road safety [12–16]. This framework uses six hierarchical, cohesive, and interactional levels to describe a system; government, regulations, company, management, staff, and work. The framework has subsequently been added to (as shown in Fig. 1), to include two additional levels above government (i.e., national and international committees) and adapted to the road safety domain [16, 17]. Decisions and actions, as well as the multitude of interactions between actors at different levels of the system, combine to produce system performance, whether that be successful or otherwise (in the case of crashes).

Based on this framework, Rasmussen [11] proposed an Accimap approach to analyze accidents in complex sociotechnical systems. This uses a hierarchical, graphical representation to display actions and decisions involved in producing the system in which an accident was permitted to occur. By applying Rasmussen's risk management framework and its associated Accimap technique, the accident investigator is able to identify influential contributory factors across various levels of a system. Given the identified factors of accidents residing in different parts of the sociotechnical system, a number of potential safety interventions and policy implications could be developed to make road systems safer.

The aim of this paper, therefore, is to apply a systems-based approach, following Rasmussen's risk management framework and its associated Accimap technique, to analyze a typical downgrade truck crash involving brake failure on a mountain road in Vietnam. From this analysis, recommendations on policy adjustment and appropriate countermeasures are made to reduce, in the future, the chance for these types of collisions in Vietnam as well as in other countries facing similar problems.

2. Methods

This research examined a downgrade truck crash that happened on March 22nd, 2018 on National Highway No.6 (NH6) in Hoa Binh - a province of Northern Vietnam. In this collision, a truck experienced a brake failure while traveling downhill on a mountain road and then crashed into a passenger car and a rock cut-slope. In line with previous studies (e.g., [12, 16]), to develop the Accimap model of this accident, the first recourse was made to an actor map presenting the actors comprising the whole road safety system. Through a critical literature review and using various sources of information relating to the responsibility and effects on road safety of the different organizations and stakeholders involved, McIlroy et al. [17] developed actor maps representing the road safety systems for five countries; Bangladesh, China, Kenya, the UK, and Vietnam. In this present research, the actor map for Vietnam was employed as a starting point to explore the significant factors that adhered to the occurrence and severity of the crash under study.

To arrive at a detailed description of the nature of the crash under the analysis, various sources of information were used. Firstly, the reports from the Directorate for Road of Vietnam (DRV) on road traffic accident black spots at the road sections within which the crash occurred and the on-site traffic accident investigation reports from the traffic police office were collected. Secondly, a variety of site visits and field investigations were conducted on the accident black spots and the road sections. Furthermore, a number of interviews on the crash and traffic safety problems of the road sections with various individuals including the drivers and passengers involved in the accident, and

their family members; local traffic policemen, and local traffic authorities, etc. have been also made. The data were collected during approximately 8 months, from February 2018 to September 2018.

An Accimap for the crash under this study was then separately developed by two authors of the present paper by using the collected data. During this, all features of the crash were deeply examined to determine all the actors represented in the actor map that have been potentially affected by the crash as well as all decisions/actions/failures related to this accident. These were then put across the Accimap levels, and the links between them were specified. The first draft of the Accimap was then reviewed and discussed by all members of the research team. The comments from three UK researchers were also gathered. Any disagreements were discussed before the second draft of the Accimap was obtained. The second draft of the Accimap was then subject to discussions with local subject matter experts, with their comments used as the basis for additional edits to the Accimap. This process was repeated iteratively until consensus among subject matter experts and researchers was attained, and the Accimap finalized.

3. The crash

The crash under examination occurred on a road section of the National Highway No.6 (NH6; also known as Asian Highway 13) located in a mountainous region of Hoa Binh province, Vietnam. The crash happened at the end of the road section of a continuous and long downgrade hill that contains various sharp horizontal curves. The starting point of this downgrade section is the Thung Khe mountain pass which is approximately 11.6 km far from the crash's location. The crash involved a truck traveling down from the pass at high speed, having, at some points, defective use of the brakes. After trying to navigate a series of curves including a number of sharp curves, this goods vehicle collided with a passenger car in front on the last curve of the road section. Based on the truck driver interviews and on-scene investigations, the location where his truck experienced a brake malfunction was ascertained to be approximately 8.4 km from Thung Khe pass (3.2 km from the crash site) as shown in Fig. 2.

Figure 2. The road section before the crash location

After the collision, the truck drove the passenger car to the roadside safety barriers on the right-hand side. As shown in Fig. 3, the barriers were constructed by deposed rubber wheels and a steel frame. The truck then jumped over the car and a part of its body slid on the top of the barriers until it turned over on the carriageway. The crash made the car severely damaged, however fortunately, individuals involved in this crash (i.e., the truck driver, the car driver, and the car passengers) survived, though their injuries were rather serious.

The truck driver was born in 1989 and he obtained a truck driving license in 2010. From 2010 to 2015, he was recruited by a variety of individuals to work as a car driver. In 2015, he bought the truck

Figure 3. The location of the crash

on an installment plan and employed this vehicle as a commercial transport service for local people. His transport routes were flexible and were subject to the demand of his customers. This driver used to travel about four or five times per month, with each job lasting one or two days. Before the crash, he experienced driving much in the low-lying, plain regions and his traveling routes were rarely through mountain regions. The crash under the current study was on the route to Son La province which was the first time the driver traveled on, and he had never experienced driving on such a severe mountain road as NH6 before.

On the day of the accident, the truck driver embarked at about 7:00 AM from his home in Ha Trung district, Thanh Hoa province, intending to travel to Son La city, Son La province. The truck was loaded with pineapple before 11:00 PM the night before. He reported being in a 'normal' condition that morning. Before starting the journey, he remembered to check his vehicle's brakes, finding them to be in working condition. About three hours after starting his journey, he reached Thung Khe pass on NH6 and took a rest there for about 40 minutes before continuing his journey. During traveling on the downhill road section from Thung Khe pass as shown in Fig. 1, the truck began to lose brake control after a situation in which the driver applied the brake firmly and suddenly due to a passenger car traveling in front of the truck, from the left side, after what he described as a dangerous overtaking maneuverer.

As shown in Fig. 4, at the time the truck driver perceived that the truck had a brake malfunction, his vehicle followed a car and another truck with a short distance between these vehicles. He continued to maneuver his vehicle using high gear and, along with the car, overtook the truck going ahead of him. The truck driver realized that switching to a low gear should be a possible way to use the vehicle engine for decelerating the truck, but he was unable to operate this. The reason was that the pneumatic system malfunctioned which had not only caused the brakes inoperable but also deterred the use of the gears. The air horn of the truck was also unusable for the same reason.

Afterward and until the collision, the truck driver tried to maneuver the vehicle on the roadway and avoid collision with other vehicles on the road. He also tried to alert other vehicles' drivers by shouting, hand waving, and clapping on the vehicle door. Two passengers of the truck were very scared at the time and decided to jump out of the vehicle and then they got injured. When the truck approached the curve presented in Fig. 3, the truck had its highest speed and rapidly reached a passenger car. As could be seen in Fig. 4, the truck driver intended to overtake the car, however, due to another truck coming in the opposite direction, it was unable for him to deter a collision between his truck and the passenger car in front.

The passenger car's driver involved in the accident was traveling on the route from Hanoi to Son La. The location of the accident site is about 140 km far from Hanoi. The passenger car was a new vehicle and had just started its journey. This car's driver was a local taxi driver who had obtained his driving license more than 15 years ago and had considerable experience in driving, particularly

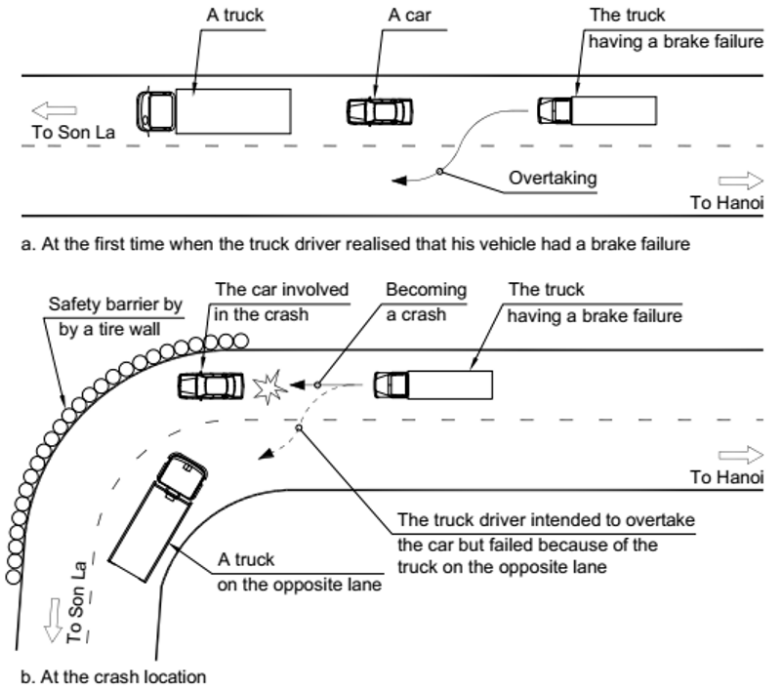

Figure 4. The diagram describing the location of the truck involved in the crash at some time points

many times driving on the road sections where the crash under this study occurred. At the time of the collision, he was talking with his passengers and he had not recognized any signal of the dangerous status of the truck behind him.

It should be noted that the road section from the Thung Khe pass to the crash site passes through severe mountainous terrain, therefore the geometric characteristics of the highway were highly constrained, necessitating a number of small radius curves and steep grades. The curve where the accident occurred has a deflection angle of nearly 90 degrees and a radius of only 60 meters and lies at the end of a long downhill road section. According to Regional Road Management Unit No.I.1 (the local road authority working under the Directorate for Road of Vietnam; DRV), during the ten years from 2008 to 2018, since the road underwent improvement works following a loan from the World Bank, more than 10 similar accidents leading to more than 10 fatalities and a number of injuries have occurred on the road section. In 2017 alone, there were three crashes, causing one death [18]. All three crashes involved semi-trailers losing their control while traveling, downgrading, and colliding into the roadside barriers or rock cut-slope at almost the same location as the crash under the study.

Information from local traffic police and the road management authority has also shown that a number of run-out-of-roadway crashes have occurred at different points along the road section, most of which were explained in terms of brake failure. As a reaction to this serious traffic accident problem, at the end of 2017, tire walls (i.e., roadside safety barriers formed by deposed wheels and steel frame) were constructed at two horizontal curves on the road section, including the curve where the crash under analysis happened.

4. Results and discussion

4.1. Results

Fig. 5 showed the final Accimap for the crash under analysis. As can be seen from the Accimap, contributory factors were identified across different levels of the road safety system, each of which

had some impact on the outcome.

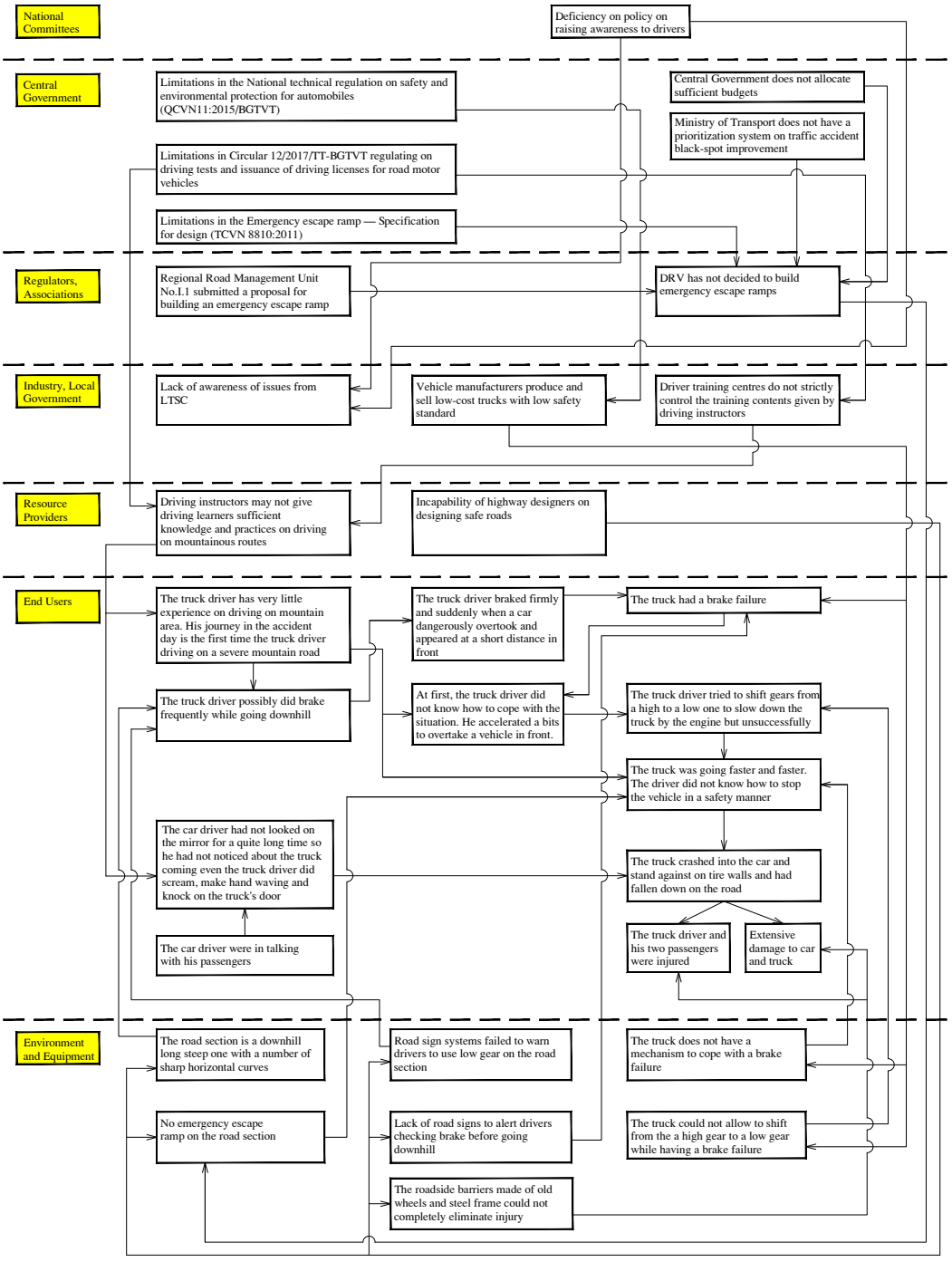

Figure 5. Accimap for the accident under study

As presented in Fig. 5, at the bottom level, Environment and Equipment, roadway and road sign characteristics, roadside safety barriers, and truck characteristics are factors contributing to the crash and its consequences. As described above, the downhill road section is steep and long with a lot of sharp horizontal curves. These conditions increase the risk of having a brake failure or losing control,

given the additional physical stresses placed on the vehicle's components. Emergency escape ramps are often used as a traffic safety countermeasure for such mountain road sections; however, no such emergency escape ramps existed on the road section under analysis. If there was an emergency escape ramp between the points where the truck brake failure was first recognized and the crash location, the accident may have been averted. Regarding road signage, there were several signs posted to warn the driver of the steep downhill road section. Although signs with a message of "slow down and use low gear when going downhill" are posted at some locations, the signage system seems to have failed to sufficiently alert the driver to the dangers of the driving environment. There is no sign to suggest to drivers to check their brakes while going downhill, a limitation that would be easily addressed. Interestingly, the truck driver said that he did not notice the signs, and as such did not consider using low gears while on the downhill road section.

The tire wall, i.e., the roadside barriers constructed by deposed wheels and steel frame, which is an initiative of the DRV in response to the safety issue of the road section, worked quite effectively in the accident. If the barriers were not installed, the accident may have been considerably more serious; however, the tire wall still did not completely eliminate injury, suggesting that improvements could be made. With regards to the truck's characteristics, firstly the truck does not have any mechanism to cope with brake failure, despite it being a well-known issue. Secondly, the truck driver said that he was not able to shift from a high gear to a low one, due to the functioning of the pneumatic system controlling both brakes and gear changes. Add to this is the non-functioning of the air horn, being operated by that very same pneumatic system, and other road users could not be alerted to the situation the driver was facing. Thus failure in one underlying system meant the removal of two possible avenues for incident consequence reduction (namely deceleration through gear change and increased noticeability through horn use).

The End Users level shows the contribution of the truck driver and car driver to the accident, as well as the sequences of events leading to the accident. The combination of the truck driver's inexperience and lack of knowledge and skill in driving on mountainous roads played a significant role in the accident. In the interview with this paper's authors, the truck driver stated that he did not remember how much he had used brakes before the incident, but that he believed he had used brakes in a normal way, i.e., used as necessary, without considering the possibility of having a brake failure. If the driver had been made more aware of this possibility, he might have tested the brake frequently rather than only using it firmly and suddenly when conditions immediately called for it. After realizing that the brakes were not functioning, the truck driver lacked the knowledge and experience to properly cope with the situation. He said that at the time he noticed the brake failure his truck speed was not high, at around 40 km per hour. At that time, given the relatively low speed, it may have been possible, even without the pneumatic system working, to have changed from the high gear to a lower one. Later the truck driver tried to change the gear, however, the truck mechanism did not allow the change when the truck was at high speed at that time.

Regarding the car driver, he acknowledged that he did not frequently look in the mirror while driving on the route that day and that at the time of the crash, he was talking with his passengers. It should be noted that the truck driver had tried to alert other road users by shouting, hand-waving, and knocking on the truck's door. If the car driver had been looking frequently in the mirror, he might have noticed the abnormal behavior of the truck and acted accordingly in response.

There are two factors that driving instructors and highway designers were included in the level of Resource Providers. Driving instructors may be partly responsible for not giving driving learners sufficient knowledge and practice on driving on severe mountain roads. Highway designers may partly

contribute to the deficiency of the roadway and road signs as pointed out earlier.

At the level of Industry and Local Government, several factors influencing the crash have been identified, including; Local Traffic Safety Committee (LTSC), vehicle manufacturers, and driver training centers. With regards to the LTSC, a number of similar accidents at the site had happened before the study accident occurred; however, the LTSC did not have a strong voice on the issue, failing to urge relevant organizations and authorities to have appropriate responses. Vehicle manufacturers have the responsibility of producing and selling low-cost trucks with low safety standards. Driver training centers contribute indirectly, through driving instructors, to drivers' insufficient knowledge and practice of driving on mountain roads; it is commonly known in Vietnam that they often do not strictly supervise their instructors regarding the contents of driving lessons.

Only one actor was identified at the level of Regulators and Associations, the Directorate for Roads of Vietnam (DRV). This organization has the power to propose and select traffic safety improvement projects; however, despite a proposal to build an emergency escape ramp submitted by the Regional Road Management Unit No.1 (which is an organization working under the DRV), the DRV has not made a decision to build the ramp, giving budget constraints as justification.

At the central government level, the limitations on standards and regulations, budgetary constraints, and a lack of prioritization of road safety improvements are contributing factors to the accident. Three regulations and standards in particular were found to be relevant to the accident. Firstly, the national technical regulation on safety and environmental protection for automobiles (QCVN09:2015/BGTVT) issued by the Ministry of Transport [19] does not stipulate the requirements of, and testing methods for ensuring vehicle brakes work well even after traveling down steep downgrade sections such as that under the current examination. If this deficiency is improved, vehicles with safety standards like the truck in the crash would not be approved to be used. Secondly, the Ministry of Transport issued Circular 12/2017/TT-BGTVT regulates driver training, driving tests, and issuance of driving licenses for road motor vehicles [20]. This circular does not force learner drivers to practice driving on mountain roads or require driving license candidates to drive in such environments during testing. These limitations contribute to the fact that the truck driver in the accident lacked experience and skill in such circumstances. Thirdly, there are no explicit criteria for a requirement for building emergency escape ramps stipulated on the technical standard of "Emergency escape ramp – Specification for design" (TCVN 8810:2011) [21]. This shortage accompanied by budget restrictions and the lack of a prioritization system for improving traffic accident black spots is the essential reason why the postponement of the DRV on constructing an escape ramp had occurred.

Deficiency in policy on raising awareness of drivers is identified as the only factor at the top level of national committees. It is a fact that in Vietnam up to date, there has been no issued policy by the National Traffic Safety Committee stipulating the requirements for local governments and other relevant organizations to raise public awareness of traffic safety problems.

4.2. Discussion and recommendations and traffic safety interventions

The results of the Accimap model have shown driver's inexperience, vehicle's poor quality, and severe road conditions to be variables directly leading to the accident, a finding largely in line with previous studies [6, 8]. However, these are just the immediate causes; although in many cases they explain how the accident occurred, they do not explain why and do not help intervention designers wishing to have an impact across situations. In addition to these proximal causes, the Accimap model also brings attention to the distal factors, factors at upper levels of the Vietnamese road transport system, that had important, indirect effects on the outcome. These are the factors that shaped the environment, or the system, from which the collision emerged, and all of these factors should be

considered when designing traffic safety interventions, as it is these factors that influence outcomes across different situations. Rather than only treating the site at which a specific incident occurs, recommendations made at these levels could treat the generic class of accidents, thus providing benefits across situations.

Based on the Accimap model, therefore, recommendations for traffic safety interventions at different levels on the Accimap model were made. These are summarized in Table 1. The following are several key potential areas for reducing the likelihood and severity of downgrade truck collisions on a mountainous road in Vietnam.

First, since the truck driver's inexperience and lack of skill in driving on a severe mountain road could be considered as direct causes of the crash, Vietnamese drivers should be well educated and trained in order to reduce such types of accidents. To do this, the driving training curricula should include an explicit requirement to experience driving in a variety of different road environments. The operation of driver training centers should be strictly monitored, and they should be required to strictly force driving instructors to give driving lessons that conform to the curricula. In addition, given the significant number of mountain roads in Vietnam, the content of the driving test should include the testing of relevant driving skills in these environments.

Secondly, improving road infrastructure is definitely a way to prevent downgrade truck collisions and reduce their consequences. In the case of the truck crash under the current study, improvements in various road features, such as road sign systems, roadside barriers, road alignment, and emergency escape ramp (see Table 1), would have enhanced road traffic safety. To facilitate this, several things should be done at the upper level of the Accimap (see Fig. 5). First, it is necessary to enhance the capacity of highway designers in designing a safer road system. In addition, a sufficient budget for traffic safety improvement should be allocated and a reliable prioritization system for selecting traffic accident black-spot improvement projects should be developed. Furthermore, the technical standard of "Emergency escape ramp – Specification for design" (TCVN 8810:2011) should be revised in which the criteria for a requirement of building an emergency escape ramp should be clearly specified.

Thirdly, the quality of the vehicle was also a concern. Despite the truck in the accident being quite new (it was bought as new and started entering into operation in 2015), its braking system was not suitable for some road environments. In addition, as aforementioned the truck did not have a mechanism to cope with a brake failure, with failure of the pneumatic system also rendering impossible the changing from a high gear to a low. Therefore, the Ministry of Transport of Vietnam is recommended to revise the National technical regulation on safety and environmental protection for automobiles (QCVN09:2015/BGTVT) which describes the requirements and testing methods that ensure vehicle brakes are able to work well in all environments reasonably expected to be experienced when driving in Vietnam.

Lastly, more efforts should be put into raising public awareness of the issue of downgrade truck collisions and reinforcing the cooperation between different stakeholders to quickly respond to traffic safety issues including the crash under analysis above. As shown in Table 1, NTSC should issue a strong policy to facilitate raising public awareness of these specific traffic safety issues. In addition, NTSC and LTSC need to be given powers to force relevant organizations to quickly solve the identified traffic safety problems. Furthermore, road authorities such as the DRV should be required to quickly propose and implement traffic safety improvement projects, reacting to the voice of local government and the public.

Table 1. Crash event and recommendations based on the developed accimap model

Level	Crash event	Recommendations
National Committees	There has been no available policy by NTSC stipulating requirements for local governments and other relevant organizations to have obligations on raising public awareness about specific traffic safety problems including downgrading truck crashes due to a brake failure.	A strong policy should be tailored to facilitate raising public awareness of specific traffic safety problems.
Central Government	QCVN09:2015/BGTVT issued by the Ministry of Transport has a limitation that does not specify requirements of and testing methods for ensuring vehicle brakes to work well even after traveling down steep downgrade sections.	The requirements for and testing methods of ensuring vehicle brakes to work well on mountainous roads should be added in QCVN09:2015/BGTVT.
	The Ministry of Transport does not force learner drivers to practice driving on mountain roads and does not require driving license candidates having to perform their driving skills on a mountain route.	The Ministry needs to improve the driving training curricula to reflect real-world driving conditions in Vietnam.
	Lack of explicit criteria for a requirement for building emergency escape ramps on TCVN 8810:2011	Explicit criteria for a requirement for constructing an emergency escape ramp should be developed and included in the technical standard.
	Budgets for implementing traffic accident black-spot improvement projects have not been sufficiently allocated by the Central Government.	Sufficient budgets should be allocated for traffic safety improvement projects.
	No prioritization system for traffic accident black-spot improvement is available (Ministry of Transport).	A reliable prioritization system should be developed.
Regulators and Associations	DRV has not constructed emergency escape ramps on the road section.	DRV should be responsible for quickly executing traffic safety improvement projects as a response to the voice from the local government.
Industry, Local Government	LTSC does not have a sufficiently strong voice in forcing relevant authorities/organizations to quickly react to the traffic safety issue.	LTSC needs to be given powers to force relevant authorities/organizations to rapidly solve the identified traffic accident problems.

Level	Crash event	Recommendations
	Vehicle manufacturers produce and sell trucks with a low quality of brake system (i.e., easy to experience a brake failure; no mechanism to deal with a brake malfunction).	Vehicle manufacturers should be required to produce and sell vehicles with a good braking system.
	The driving lessons provided by driving instructors were not well controlled by driver training centers.	The centers need to be required to be strictly supervised by their driving instructors to give driving lessons conforming to the regulations.
Resource Providers	Driving instructors may not be given sufficient training nor allow for enough practice on mountain roads.	Driving instructors should be required to give more lessons and practice time related to driving on mountain roads including skills to cope with dangerous situations such as having a brake failure.
	Highway designers lack the capability of designing safe roads in mountain regions.	Highway designers should enhance their capability on designing safe mountain roads.
End Users	The truck driver had a very poor experience on driving on a mountain road and he lacked the knowledge and skill to cope with a brake failure on a mountain road. The car driver did not look in the mirror for a rather long time.	Drivers should be educated and practiced about driving on mountain roads including the skill to cope with a brake failure and checking the surrounding environment frequently.
Equipment and Environment	The road section is severely steep and on a long downhill with various sharp horizontal curves.	The road alignment should be improved.
	No emergency escape ramps are available on the road section.	Emergency escape ramps should be built.
	The existing road sign systems had no positive effects on alerting drivers to use low gear on the road section and check their brakes before traveling downhill.	The road sign systems should be redesigned.
	The roadside barriers constructed by deposed wheels and steel frames did not completely prevent injury.	The design of the barriers should be improved.
	The truck does not have a mechanism to deal with a brake failure and cannot change from a high gear to a low one when a brake failure occurs.	The limitations of the truck should be improved.

5. Conclusions

The present study is the first effort to apply a systems-based approach, following Rasmussen's risk management framework and its associated Accimap technique, to the analysis of a typical downgrade truck collision on a mountain road in Vietnam. The results of the Accimap model have shown that the driver's inexperience in driving on a mountain road together with low quality of vehicle and severe road conditions were those factors that directly contributed to the occurrence and consequences of the incident, but that these contributory factors were themselves caused by higher system factors. The model gave representation to the various limitations and shortcomings of different actors across each level of the socio-technical system that is road transport in Vietnam. Recommendations for traffic safety interventions through police adjustments were proposed, including the responsibilities of different actors on enhancing drivers' skill and experience; improving roadway conditions; ensuring vehicle quality; raising public awareness, and; reinforcing the cooperation of different stakeholders in solving traffic safety problems in Vietnam. Since, due to limited resources, only one typical crash was deeply investigated in this research, replication of this study with more crashes of the same type in different regions of Vietnam was recommended to generalize the findings over downgrades in the whole country.

Acknowledgments

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