Fleet Safety Management Practices in Hazmat Transportation: Challenges in Thailand

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Abstract

Transportation by land is essential for the distribution of hazardous material (hazmat) in Thailand and many countries. However, it also represents a significant road safety risk because of the consequences associated with crashes involving hazmat loads and heavy vehicles. The aim of this study was to examine current fleet safety management practices implemented by hazmat carrier companies in Thailand. Hazmat fleet managers completed an interview about their safety management practices. A preliminary analysis of an empirical study points to gaps in the practices of carriers, and identifies challenges carriers have complying with traffic safety regulations.

A total of 32 carriers participated in the study. Examination of safety practices and policies revealed that most of the carriers perceived driver reinforcement as a successful practice in managing safe driver behaviour. Driver monitoring using GPS was also chosen as a good practice to reduce the risk of crashes. However, most carriers failed to implement important policies, for example, control of hours of service. The study provides an insight into the deficiencies of safety management in hazmat fleets that are relevant for many countries concerned with hazmat transport. The findings of this exploratory study should guide researchers interested in policies and practices to prevent hazmat crashes in Thailand as well as other countries.

Keywords: Safety management practices, best practices, hazmat transport, fleet safety

1. Introduction

Although considered as a low probability event, crashes associated with hazmat transport pose a significant road safety risk to human life, property, and the environment (Brown and Dunn 2007). The US Federal Motor Carrier Safety Administration (FMCSA) (2001) has estimated that economic losses from a hazmat crash are higher than for a non-hazmat crash, especially a crash that results in a fire or explosion. The FMCSA has also reported that for the US the average number of hazmat crashes is 0.32 per million vehicle-miles. Because of these consequences, hazmat crashes raise serious concerns for all stakeholders involved in and affected by such traffic (Samuel *et al.* 2009). The transportation of hazmat usually occurs in the context of a complex and dynamic institutional environment (Carnes 1986). Hazmat vehicles are moving risk sources (Bubbico *et al.* 2004). Routine work tasks are also essentially carried out without supervisory oversight (Malone 2004) and completed under time pressure. The combination of all these factors requires hazmat carriers to play an active role in preventing road crashes and to have a special focus on driver safety.

1.1 Hazmat transport situation in Thailand

Hazmat transport is vital to the Thai economy, underpinning a diverse range of industries and activities. The use of hazmat in the industrial, agricultural, and public health sectors has increased rapidly in recent years (Decha 2005, Chartsirisup 2006, Thailand Environment Institute 2011). As a consequence, hazmat trucks have been appearing on Thai roads in increasing numbers and are the most dominant mode of hazmat transport (TransConsult Company Limited 2007, Land Transport Association of Thailand 2009). The

Thai Department of Land Transport (2011) has estimated that the total number of registered vehicles in the country is 28 million, of which the number of general trucks is about 1 million. 10,000 of these trucks are registered to transport hazmat commodities. The same source has also reported that the current number of hazmat truck drivers is 91,244 (Department of Land Transport 2011). It is worth noting that there seems to be a disparity between the figures of hazmat vehicles and drivers. This raises concerns regarding the enforcement of hazmat truck registration and the validity of the registration system itself. Interestingly, the annual projected demand for drivers has continued to increase considerably since 2008 (Office of the National Economic and Social Development Board 2008, Chanthorn 2011). The number of trucks used for general and hazmat transport has been increasing steadily in recent years and there are between 50,000 and 70,000 new trucks registered annually, a growth rate of over 10% per year (Chanthorn 2011). Moreover, in 2002, nearly 20 million tons of imported hazmat was transported from the central port of Bangkok to the industrial regions via several main national highways. Nowadays, a greater amount of hazmat that is imported, exported, and produced domestically is transported via Thailand's national road network (TransConsult Company Limited 2007).

Given this situation, it can be assumed that the risk of hazmat vehicle crashes is high and is increasing. Unfortunately, accurate nation-wide statistics on hazmat truck crashes are not available (Chartsirisup 2006, TransConsult Company Limited 2007). There is no single federal database maintained by government agencies that records hazmat crashes and related incidents. The lack of hazmat database management and crash surveillance is one of a number of critical failings in hazmat road safety management. Moreover, past governmental efforts in solving and preventing crashes caused by hazmat transport have proved to be inefficient according to analyses by Waranusantikul (2009) and the Thailand Environment Institute (2011). These authors agree that some carriers and drivers involved in the transportation of hazmat may lack responsibility, awareness, and care in the use, distribution, and transportation of hazmat. Recent studies also report that Thai drivers' aberrant behaviour, such as violating road rules or driver errors has been a leading cause of past hazmat crashes (Chartsirisup 2006, Waranusantikul 2009). To date, there has been only sporadic adoption of safety interventions in not only hazmat fleets but also general fleets in Thailand (Waranusantikul 2009, Hazardous Substance Logistics Association 2011).

1.2 Fleet safety management practices: benefits and challenges

The current situation of hazmat transport in Thailand highlights the serious need for safety management programs within hazmat fleets. It is widely recognised that the management of safety plays an important part in achieving and maintaining safety standards. Safety management practices (SMPs) are a vital ingredient of comprehensive safety management systems. SMPs can influence and shape employees' attitudes towards the importance of safety and can contribute to their safe behaviour. SMPs have been found to have positive effects on increasing driver safety perception (Newnam *et al.* 2008), driver safety behaviour (Newnam *et al.* 2002, DeJoy *et al.* 2004) and reducing crash rates (Moses and Savage 1994) in general fleets. Specifically, particular SMPs have been reported to be associated with positive safety outcomes. For example, Mejza *et al.* (2003) reported the effects of driver hiring practices, driver training, and reinforcement activities and Park *et al.* (2005) reported positive effects from the control of hours of service.

In highly hazardous workplaces and industries, such as in the distribution of hazmat commodities, the importance of safety management is even more apparent (Reniers et al (2005)). While transport of this kind is highly regulated and monitored in developed countries, in Thailand, SMPs implemented by hazmat carriers are sporadically adopted. The central legislation (i.e. the Announcement of Dangerous Goods Transport Committee:

Dangerous Goods Transportation by Land B.E. 2545 (Hazardous Substance Committee 2002)) designates safety performances to be the responsibility of carriers. The carriers must manage their drivers to ensure compliance with legal requirements, i.e. driver selection, restricted routes, working time, speed monitoring, and safety communication. However, the standards of such mandatory practices are less stringent compared to legislation in highly regulated countries. The Thai Government's position is that the carriers are responsible for putting SMPs into effect to meet such standards. Currently, there have been few interventions from Thai road safety government agencies to support the carriers regarding the translation of these requirements into SMPs in a hazmat fleet setting. This raises some difficulties for the carriers when implementing SMPs. Firstly, the lack of support provided may make carriers confused as how to establish SMPs and as to which SMPs should be implemented to meet the requirements. Secondly, implementation of safety interventions often involves substantial expenditure and resources (Krasus 2005) and the positive impact of an intervention may not be immediate (Robson *et al.* 2007). These aspects may discourage carriers from adopting effective SMPs.

The present study focused on hazmat carriers and aimed to identify particular safety management practices that have been adopted by hazmat fleets in Thailand. More specifically, the objectives of the present study were (1) to investigate the current patterns of hazmat fleet SMPs adopted by hazmat carriers in Thailand and (2) to examine which SMPs were perceived by hazmat carriers to be associated with good driver safety outcomes. Knowledge of safety management-related activities performed by hazmat carriers is essential to inform future analyses e.g. investigating the relationship between SMPs and driver safety outcomes, and the benchmarking of SMPs with carriers in highly regulated countries.

2. Method

2.1 Study design

The present study was exploratory and survey-based. A cross-sectional survey of a sample of Thai hazmat carriers was used. Verification of the content validity of the survey questionnaire was also conducted by Thai experts to ensure coherence of questionnaire items with respect to the Thai hazmat transport context.

2.2 Participants

The sample unit in this study was a safety management representative with at least 2 years experience in their current position, i.e. a hazmat fleet manager responsible for safety. This particular person was chosen because they had responsibility for allocating resources to SMP implementation in a company and also had access to information about specific practices being carried out in the organisation, including a practice's effectiveness and associated difficulties. To recruit the participants, hazmat carriers registered with the Thai Department of Land Transport were included. Company selection was limited to those that were located in the four provinces that had the highest amount of hazmat transport activity. Companies that did not have full contact details were excluded. One hundred (100) carriers were then randomly selected from the eligible list. An initial letter was sent to the hazmat carriers, via post, to invite a fleet manager to take part in the study. This was limited to one representative from each company. A consent form was delivered in person or via mail to those fleet managers that indicated an interest. The representatives were then contacted to schedule a time for the questionnaire administration. In total, 32 representatives from 32 hazmat carriers participated in this study.

2.3 Measures and procedures

The questionnaire was divided into 2 sections. The first section was self-administered by the participants. The participants supplied information about the company, e.g. experience, number of vehicles, type of hazmat, and length of trip. Such information was completed using either multiple choice or open-ended responses. Participants ticked the choices which best described their characteristics or supplied a short answer to the open-ended questions.

Section 2 collected information about fleet safety management practices via interview. The participants completed a short, semi-structured interview face-to-face. Open-ended questions were asked and answers from the respondents were recorded on a paper-based form by the investigator. Information about current safety management practices adopted by the fleet was collected. This included information about the SMPs that were perceived by the fleet managers to best control driver behaviour and reduce crash risk. These questions were asked without additional prompts and the number of SMPs reported by the participants was not limited. Factors contributing to the success of SMPs were also noted. The last set of questions asked about specific SMPs that were important for the hazmat fleet. The respondents answered whether such SMPs had been adopted by the fleet or not. If so, a detailed explanation of implementation was also requested.

2.4 Data analyses

Descriptive statistics were used to describe the patterns of carrier characteristics completed in Section 1. This analysis was performed using the PASW program version 18.0 for Windows. The interview data regarding the implementation of SMPs in Section 2 was coded and analysed to examine current patterns.

3. Results

3.1 Characteristics of the sample hazmat carriers

A summary of the descriptive characteristics of the sample carriers is presented in Table 1. The most reported characteristics are highlighted in bold type. Half of the sample carriers had between 11 and 20 years experience in the hazmat transport industry. Only two of them (6.25%) had less than 5 years experience. 71.88% of carriers were certified for the international quality management system standard (ISO 9000 (International Organisation for Standardization 2011)). Three carriers (9.38%) had achieved the local safety management system standard (TIS 18000 (Thai Industrial Standards Institute 2011)) and two carriers (6.25%) had achieved the international safety management system standard (OHSAS 18000 (The Occupational Health and Safety Group 2011)). The most frequent hazmat transported was flammable liquids at 56.25%, followed by corrosive substances at 46.88%. Just over half of the carriers used a 10-wheel truck to transport their hazmat. The numbers of hazmat trucks in fleets were most commonly between 11 and 50 at 40.63 %. The average distance per trip was 101 – 400 kilometres that were reported by 53.13% of carriers. Lastly, about half of the carriers had annual fleet vehicle kilometres travelled of less than ten million. Five carriers (15.63%) did not record this information.

3.2 Patterns of safety management practices

3.2.1 Best SMPs selected by the participants to control aberrant driving behaviours

The sample fleet managers' perception of the SMPs, implemented in their fleets, which most effectively controlled aberrant driving behaviour was investigated. The participants indicated that "driver reinforcement" using incentives/disincentives was the best SMP at 53.13%. "Driver training" and "supervision and monitoring using GPS" followed at 43.75% each. Figure 1 shows the best SMPs as reported by the participants.

Table1 Descriptive characteristics of the sample hazmat carriers

Characteristics	n = 32	%	Characteristics	n = 32	%
- Experience in hazmat transport industry (years)			*- Fleet vehicles km travelled (x 10^6 kilometres)*		
< 5	2	6.25	**< 10**	17	53.13
6 – 10	11	34.38	11 – 30	7	21.88
11 – 20	**16**	**50.00**	> 31	3	9.38
> 20	3	9.38	Did not record	5	15.63
- Management system certified [a]			*- Types of hazmat trucks* [a]		
ISO 9000	**23**	**71.88**	4 wheel	3	9.38
ISO 14000	5	15.63	6 wheel	9	28.13
TIS 18000	3	9.38	**10 wheel**	**18**	**56.25**
OHSAS 180000	2	6.25	More than 10 wheel	8	25.00
			Trailer or semi-trailer	15	46.88
- No. of hazmat trucks in fleet			*- Distance per trip (kilometres)*		
1 – 10	6	18.75	< 100	8	25.00
11 – 50	**13**	**40.63**	**101 – 400**	**17**	**53.13**
51 – 100	3	9.38	401 – 700	4	12.50
101 – 500	8	25.00	> 700	3	9.38
> 501	2	6.25			
- Types of hazmat transported [a]					
Explosives	0	0.00			
Gases	10	31.25			
Flammable liquids	**18**	**56.25**			
Flammable solids	2	6.25			
Toxic and infectious substances	2	6.25			
Radioactive material	1	3.13			
Corrosive substances	15	46.88			
Oxidizing & organic peroxides	1	3.13			
Miscellaneous dangerous	4	12.50			

[a] *Participants could choose more than one option, so percentages do not sum to 100%.*

3.2.2 Best SMPs selected by participants to reduce risk of vehicle crashes

The participants were asked about the best SMPs they thought reduced the risk of hazmat truck crashes in their fleets. 56.25% of the fleet managers perceived that "speed control using GPS" was the most effective SMP to reduce the rate of crashes. The practices “control of hours of service” and “driver training” were reported at 28.13% each. Figure 2 presents all SMPs reported.

3.2.3 Factors contributing to effectiveness of SMPs

When asked about factors contributing to the effectiveness of SMPs, the participants reported the two most important factors were “management commitment” and “drivers’ intrinsic safety values”, both at 34.38%. They were closely followed by “communication within organisation” (Figure 3).

3.2.4 New SMPs to be implemented

This question asked about SMPs that had not been adopted in their own fleet as yet but that should be introduced to enhance fleet safety. The result is shown in Figure 4. The majority of the participants indicated that no more SMPs should be implemented in their fleets. However, a few respondents proposed some other SMPs which they felt were important such as “emergency response drills with local government and community”, “driver monitoring on the roadside” and “driver training by private agencies”.

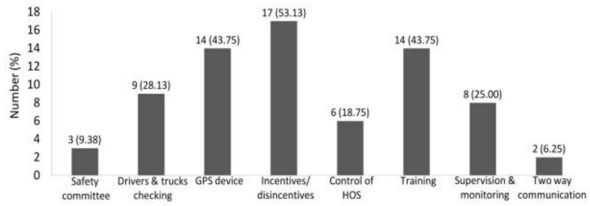

Fig. 1 Number (%) carriers identifying which SMPs are effective ways to control aberrant driving

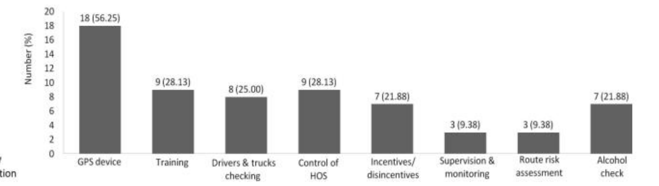

Fig. 2 Number (%) of carriers identifying which SMPs are effective in reducing risk of vehicle crashes

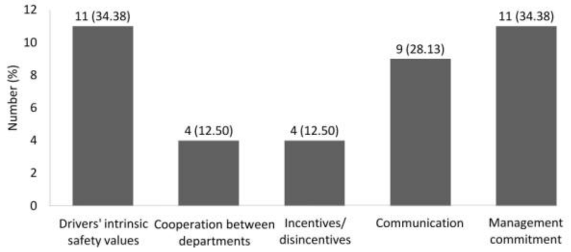

Fig. 3 Number (%) of carriers identifying which factors contributed to the effectiveness of SMPs

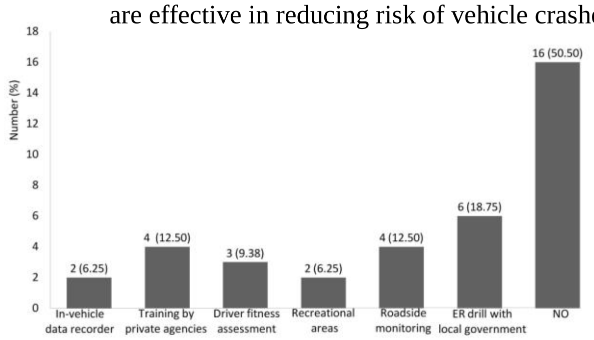

Fig. 4 Number (%) of carriers identifying new SMPs that should be implemented in fleets

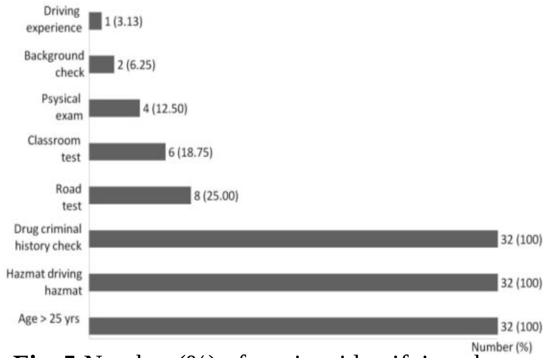

Fig. 5 Number (%) of carriers identifying characteristics of driver hiring practice

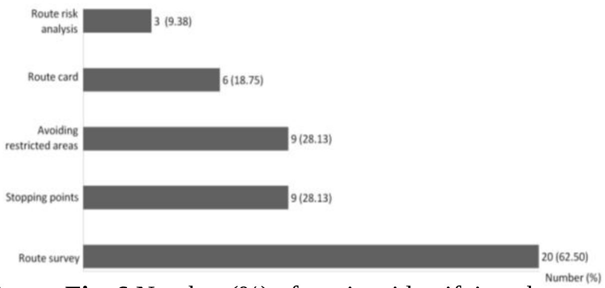

Fig. 6 Number (%) of carriers identifying characteristics of route analysis and designation

3.2.5 Driver hiring practice

The participants were asked whether their fleets adopted a SMP regarding driver hiring. The answer was recorded as a binary response, i.e. 'yes' or 'no'. All of the carriers that adopted this SMP provided a detailed description of their practices. Figure 5 presents what processes are used for driver selection among the sample carriers. All sample carriers reported complying with the driver selection criteria as required by the legislation, i.e. a minimum age of 25 years old, particular hazmat driving license, and drug criminal related history checked with the Police Department. However, other criteria, beyond the legal requirements, were only sporadically applied. Only 18.75% of the sample carriers used a classroom test for screening and 25.00% implemented an on-road driving test. Physical check-ups and past experience were less commonly employed during the recruiting process.

3.2.6 Route analysis and designation

About 72% (23 carriers) of the sample carriers had an SMP focussing on route analysis and designation. The majority of the carriers that adopted this practice (62.50%) conducted a route survey and designated the routes for drivers. 28.13% of the sample considered points/areas for truck stops during the trip and also avoided restricted areas e.g. tunnel, hazardous intersections, water reservoirs, and highly populated areas (Figure 6). 18.75% of the carriers provided a document called a 'route card' for the driver to confirm the designated route each trip. Very few of them incorporated hazmat route risk assessment as part of their route analysis and designation practice.

3.2.7 Control of hours of service

Only 20 (62.50%) respondents reported adopting control of hours of service. Daily work hours varied among fleets that adopted this SMP. Some of them (18.75%) limited daily work hours to 8 hours per day and some (21.88%) extended them to 12 hours. Rest time during the trip and hours off-duty before the next trip were specified for the drivers by 28.13% and 18.75% of carriers respectively as shown in Figure 7.

3.2.8 Speed and route monitoring

The practice of monitoring speed and route was adopted by 75.00% (n=24) of the sample carriers. Most of the carriers (75.00%) used a passive procedure, e.g. complaints from other road users because the hazmat trucks normally have signage displaying employer contact details on the body of the truck. In contrast, some carriers heavily relied on electronic monitoring devices. 40.63% of the sample used real time GPS. 34.38% of the sample used passive GPS that recorded journey details and an investigation of violations was conducted after the trip. Two carriers conducted roadside surveys to investigate drivers' aberrant behaviour. Figure 8 shows the details of the outcomes.

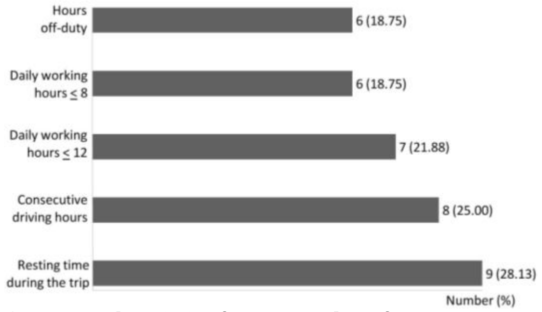

Fig. 7 Number (%) of carriers identifying characteristics of control of hours of service

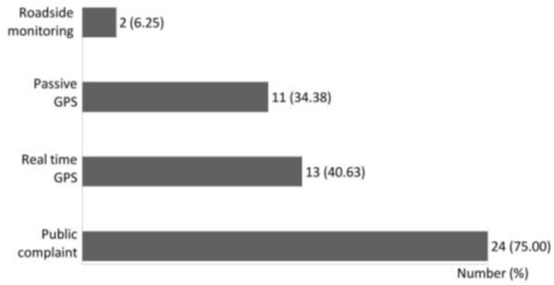

Fig. 8 Number (%) of carriers identifying characteristics of speed and route monitoring

3.2.9 Safety communication practice

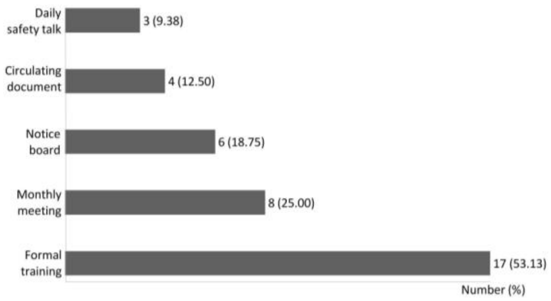

Fig. 9 Number (%) of carriers identifying different safety communication practices

Communication concerning safety issues in an organisation was also adopted by 75.00% of carriers (n=24). Formal training was mostly used as a means of communication between management and drivers. This was followed by regular meetings. Informal communication, such as through daily safety talks and using notice boards, was less popular. Figure 9 shows the breakdown of the various methods used for communication.

4. Discussion

The majority of the Thai hazmat carriers surveyed were experienced hazmat transport companies. Only two of the carriers were new to this industry. A series of local and international safety management system standards were sporadically adopted. The most transported hazmat were flammable liquids reflecting the high demand from customers for these products. Fleet sizes also varied. However, the majority of the carriers were considered to be smaller fleets with a fleet size between 1 and 50 vehicles. The distance of transport was typically a medium haul trip (less than 400 km), followed by a short haul trip (less than 100 km).

From their past experience, the sample fleet managers perceived that the best SMP to control aberrant driving behaviour (i.e., violations, errors, and lapses and vehicle crashes) was "driver reinforcement" by means of financial incentive/disincentive and rewards/punishments. This is in line with findings from prior research that reported relationships between these SMPs and driver safety outcomes. Zaidel et al. (2002) reported significant relationships between decreases in the number of crashes for general drivers and three punishment measures namely, warning letters, penalty point systems, and license revocation. Moses and Savage (1992) also reported the effect of incentives on occupational drivers. The authors found a significant relationship between safety incentive programs and the total number of crashes and injuries for carriers in the trucking industry in the United States. Harrison (2001) also suggests that rewards are effective to control fleet driver speeding behaviour. The benefits of driver positive and negative reinforcement, however, are controversial, especially when sustainable behavioural change is desired. Safety behaviours may continue to occur only if they are positively reinforced (Harrison 2001) and punished behaviour may return when the punishment is withdrawn (Staddon 1995). Moreover, driver incentive schemes can lead to underreported crashes (Murray 2006). Most importantly, the high reporting of this SMP among the sample reflects the carriers' preference for an intervention that encourages an immediate safety response. Some sample carriers voiced the importance of other SMPs, e.g. "driver training". This intervention would target a driver's knowledge and understanding of safety. In addition, because a driver educated in safety may not always be motivated by the incentives provided by the employer (Probst and Brubaker 2001), driver training may also be useful for enhancing drivers' safety attitudes (Newnam *et al.* 2008).

A majority of sample carriers utilised driver monitoring using in vehicle technology, i.e. a GPS (global positioning system) tracking device and thought it was effective to reduce crash risk. Although this technology is not mandatory and still expensive with respect to its commercial application in the Thai logistics market, over half of the sample had voluntarily adopted monitoring using GPS and reported it as the best SMP to reduce crash involvement. The main reason given was that the GPS is a tool to objectively monitor driving behaviour that, in turn, is a potential determinant of crashes. According to an analysis of the effects of in-vehicle data recorders incorporating a GPS receiver by Toledo *et al.* (2008), fleet drivers showed statistically significant reductions in crash rates. One of the sample of Thai fleet managers also suggested that *"in the past my drivers never admitted speeding violations even after several complaints had been lodged by other road users...but they cannot refuse once a GPS tracker has been installed in their trucks"*. Several fleet managers also agreed that a GPS device offers a number of safety benefits including monitoring route deviations and on-road driving behaviour, providing real-time feedback and date data for crash investigations. Another reason that may encourage the carriers to adopt this SMP is that a GPS also offers commercial benefits, e.g. monitoring of corruption of commodities, and misuse of the vehicles. Some sample carriers voiced concerns about the limitations of the GPS system, e.g. network coverage and high operating cost and they expected government involvement to improve these issues. Also, one of the fleet managers argued that *"the downside is that it makes my drivers feel like they are bad people. Feedback provided in real-time also annoys and distracts the drivers"*.

The factors that the sample fleet managers perceived to be an important contributor to the success of SMP implementation were equally "drivers' intrinsic safety values" and “management commitment”. This does not correspond to the best SMPs reported by fleet managers previously (i.e. “driver reinforcement” and “GPS monitoring”) as those practices do not deal with drivers’ intrinsic safety values. It can be concluded that, although the fleet managers realised that driver and management attitudes are crucial, in reality, the practices that encourage an immediate effect are selected first.

A few carriers requested the involvement of local government units and community (e.g. fire brigade and hospital) for periodic emergency response drills. Two of the carriers had a plan to provide recreational areas at the sites for the drivers’ families. A fleet manager said that *“a driver usually brings his family along...sometimes the driver, together with his wife and kids, sit down under the truck and have lunch”*. However, the majority of the fleet managers asserted that no more safety interventions should be implemented in their fleets. This is consistent with sporadic adoption of SMPs and somewhat reflects a low level of enthusiasm for improving fleet safety.

All sample carriers adopted driver hiring practices but only those components that are stated in the legislation. Although this practice is mandatory, criteria for hiring decisions are less stringent than the standards required in highly regulated countries. Only minimum age, type of driving license, and no background of drug criminal-related history are indicated. Other criteria, e.g. driver health and fitness, are stated merely in general. In the US, a driver pre-employment program is well established and overseen by the FMCSA. The driver qualification criteria are specified in the CFR Part 391 (Federal Motor Carrier Safety Administration 2012) with support guidance provided. The criteria cover general background of the driver, tests, physical examination, and files and records. A small number of sample carriers include such criteria for driver selection. Only 4 carriers conducted a physical examination and only eight conducted road tests. Hazmat routing control is legally required in Thailand. Nevertheless, almost 30% of the sample carriers had not adopted route analysis and designation practices. Some fleet managers revealed that their priority was cost saving and the cheapest transport route was therefore selected. Some carriers just ignored this practice and only gave the destination to the drivers. No designated route was provided.

Control of hours of service was the least common SMP adopted among the sample carriers. This finding corresponds to Jiamboonsri’s analysis (2010) that violations of hours of service regulations by heavy vehicle drivers in Thailand are believed to be common. The central hazmat legislation does not specify the drivers’ working time. However, the Thai Labour Protection (No. 2) Act B.E. 2551 specifies the maximum working time per day for a commercial driver and an employee in any industry (Ministry of Labour 2008). Specifically, an employer must not allow an employee to work longer than 8 hours per day. If an employee agrees, the limit of working time may extend to 9 hours per day but must not go over 48 hours per week. However, details of off-duty hours before the next trip are not specified in any Thai legislation. Several authors have reported a relationship between driver violations of hours of service rules and traffic crashes (Jones and Stein 1987, Corsi and Fanara 1988). More recently, Park et al., (2005) reported that crash risk increased significantly in the 5^{th} driving hour and this increase was sustained through to the 10^{th} driving hour.

Because fleet drivers’ routine work is essentially carried out without supervisory oversight, driver speeding and deviation from designated routes are of major concern once drivers depart from the fleet site. The monitoring of driver compliance to speed limits and route designation is important given that people who are aware of being observed tend to modify their behaviour (Wouters and Bos 2000). Most of the sample of Thai hazmat carriers used public feedback, via a telephone number displayed on the vehicles, to monitor their drivers. The same amount of carriers used real time GPS monitoring and passive GPS monitoring. This practice could potentially be used to encourage individuals to behave more safely when driving. Lastly, the adoption of an SMP related to safety communication indicated that formal training was preferred. Informal communication, e.g. daily talk, was less popular and mainly discussed production-related matters.

5. Limitations

This study presents the findings of a survey of safety perceptions of a sample of hazmat fleet managers. There are limitations that should be acknowledged when considering these findings. The study may suffer from self-report subjectivity with respect to the perceptions associated with the measurement of SMPs. Hence, the perceived best SMPs indicated in the study should be viewed as preliminary until they can be confirmed by the respective fleet's safety performance. Further statistical analysis to investigate the correlations between SMP implementation and carriers' safety performance is important to validate the efficacy of the SMPs. This information could then be useful for hazmat carriers who are establishing or reviewing their safety management program. Recruitment of the participants in this study was voluntary and the response rate was only 32%. This raises an issue in that the participants may comprise only carriers with good safety performance who are more interested in safety because those carriers who have poor safety performance may tend to have a general aversion to outside scrutiny. The sample size is also small which limits the statistical analysis that can be conducted and makes the results vulnerable to the effect of unusual respondents. Future research with a broader sample of hazmat carriers is important to confirm the findings of the current exploratory study and provide information to help prevent hazmat truck crashes in this industry.

6. Conclusion

This study reported findings from a survey conducted to identify current patterns of safety management practices in the Thai hazmat transport industry. Taken together, the study findings suggest that the challenges facing hazmat carriers include increasing the adoption of long term proactive safety interventions and improving the comprehensiveness of SMPs already adopted. In particular, the study suggested that:

- SMPs that encouraged an immediate safety response were preferred by carriers, e.g. driver reinforcement.
- SMPs, related to the active role of the carriers such as control of hours of service and route analysis and designation, were still only sporadically adopted even though they are legally required. These SMPs should be targeted to ensure carriers fulfil their legal obligations in fleet safety management.
- Low enthusiasm for new safety interventions among the fleet managers was noted which was consistent with the pattern of sporadic SMP adoption. This finding raises an issue regarding safety managers' perspective on their role in managing safety. Overall, the results suggest that the carriers would prefer to place the safety responsibilities on drivers and not seek to implement SMPs that may affect their resources or workloads.
- The components of each SMP in several fleets were also inadequate in regards to the Thai and international standards, e.g. driver hiring practices and control of hours of service.

Ultimately the responsibility remains with the Thai government to monitor fleet safety compliance, and to review the adequacy of current legislation. The fleet managers' call for assistance from the government with SMPs, such as emergency response drills and free software support for GPS, could be considered as an opportunity to improve the safety of hazmat transport.

In summary, the study provides an insight into current trends of safety management practices and how fleet safety in the Thai hazmat industry can be enhanced. Further studies to investigate the relationship between particular SMPs and driver safety outcomes could help target the SMPs precisely. The findings from the present study may also be relevant for other countries concerned about improving safety management interventions in hazmat transport.

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