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A New Model of Safety Management System for Railway Operation

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Abstract: Safety management systems (SMSs) were introduced to the rail industry as a proactive way to manage safety and prevent accidents. However, accidents still occur where the SMS has been implemented but ineffective. It is, therefore, of great importance to have a reality check of what the role and functions of an SMS are in order to understand why the SMS does not prevent organisational accidents and to identify the weakness of SMS as underlying causes in accidents.
This paper is a summary of the report based on previous research (Pan, 2014). It presents a systemic review of SMS elements based on analysis of accident reports and proposes an innovative SMS model in order to discover potential improvements for SMS implementation. The review based on selected accident reports focused on analysing the individual SMS elements involved in the accidents and identified the most critical elements in accidents are safety-related information management, risk assessment and competence management. The main findings from the research lie in the failure patterns of SMS elements in accidents, organisational features of the rail accidents, inadequate standards for SMS design, and industrial emphasis in implementation. We gave our recommendations on SMS implementations based on this review. And future research can be processed in the areas of improvement of the SMS model, detailed analysis of SMS involvement in the accidents, and the actual value of the SMS.
Keywords: Railway safety; Safety management; Safety management system; Management system model

1 Introduction

The understanding of railway accidents and incidents has evolved with the increasing complexity in modern socio-technical environment. Many rail accidents, such as Clapham railway accident and Ladbroke Grove accident, occurred as a result of combining factors among the organisation and safety arrangements than pure human error or individual technical failure (Qureshi 2007, Evans 2010, RRSB 2011). Those complicated events, termed as organisational accidents, may originate from decisions and actions from people at any level, and taken at times and places quite far from the final accident (Reason, 1997, Pidgeon and O'Leary, 2000). Since Safety Management System (SMS) as a proactive approach to systematically manage the safety throughout the whole organisation is widely required among the rail industry and other safety-critical industries, the benefits of adopting a SMS have been recognised across the industry (Fernández-Muñiz et al. 2007). As in rail industry, SMS has been embedded in a variety of standards, guidance and regulations across countries (Transport Canada 2001, European Union 2004, ROGS 2006, National Transport Commission Australia 2008). From both legal and beneficial perspective, an effective SMS is necessary in the railway operation to prevent potential accidents which can lead to huge losses of the organisation.

Simply having a SMS in place does not

guarantee the success in managing safety. In general, major accidents still occur in many industries worldwide where the SMS was implemented but ineffective and, therefore, it is of great value to understand why SMS does not prevent the organisational accidents and to identify the weakness of a SMS as underlying causes in the accident.

SMS is not a completely new system; rather it builds upon the existing safety principles and safety practices in the organisation to manage the safety from a proactive way (Bayuk 2008). As similar in other safety critical industries, the purpose of the SMS is to ensure safety operation through the systematic management in the railway. In UK, Railways and Other Guided Transport Systems Regulations (ROGS, 2006) states that: "safety management system is the basis for making sure a transport system runs safely and in line with ROGS."

By the time of this paper has been written, numerous research involving review and assessment of the SMS can be found in many safety-critical industries, for example in aerospace industry (McDonald et al. 2000, Gill and Shergill 2004, Liou et al. 2008, Hsu et al. 2010), in construction industry (Tam et al. 2001, Tam et al. 2002, Chan et al. 2004, Ai Lin Teo and Yean Yng Ling 2006, Giretti et al. 2009), maritime industry (Trbojevic and Carr, 2000, Sii et al., 2001, Akyuz and Celik, 2014), in chemical industry (Mitchison and Porter, 1998, GAO and ZENG, 2005), and in food industry (Luning et al., 2009, Jacxsens et al., 2009).

In the rail industry, many railway accident reports, e.g., from RAIB, do focus on aspects of the SMS (e.g. Ladbroke Grove, Potters Bar, and Waterfall). However these reports focus on particular accidents though, and there is a need to systematically examine across the entire industry, because learning from previous accidents is essential to prevent accidents by identifying the recurrent causes and potential actions for improvement. Unfortunately the existing research of statistical analysis of the accidents normally focuses on the technical parts or immediate causes. Therefore, reviewing the effectiveness of SMS from the underlying causes and contributory factors at managerial level is necessary and rewarding.

On the other hand, we have been aware that the primary scope of the research in this paper is based on the official accident reports published by the UK Rail Accident Investigation Branch (RAIB, 2014). It is limited to the rail accidents occurred as a combination of factors of individual SMS elements involved in the **reported** accidents, incidents or near misses. The focus is on the systemic review of the SMS from accident side rather than the audit based on the checklists. In addition, safety culture has a great influence on safe operation and SMS is often considered as the situational part of the safety culture (HSE, 2005). We left the study of safety culture in the future work. This paper only focuses on the structural elements of the safety management, namely the objective arrangement within the SMS, rather than the culture or subjective aspects.

2 Review of SMSs

The complex nature of accidents has been recognised by safety researchers for years. The term 'organisational accident' is proposed to describe those accidents occurred due to the concatenation causes and factors from many levels in the social-technical system (Reason, 1990). Unlike individual accident, which is frequent but less severe with limited causes, an organisational accident is defined as a comparatively rare event which has catastrophic consequences and multiple causes involving a variety of contributory factors combine to breach the defensive layers (Reason, 1997). And it worth knowing that another group of academics term such kind of accidents as 'system accidents', resulting from failures of multiple components (Perrow, 1984, Leveson, 2002). In this paper, from a managerial view to safety, we will use the term 'organisational accident', which is more intuitive to denote these modern complicated accidents involving organisational and social factors. The emerging of organisational accidents requires better and less subjective understanding of why these complex accidents happen and how to prevent future ones (Rasmussen, 1997). Somehow, the accident models, especially the organizational accident model, are more applicable in understanding the organizational accidents in socio-technical systems, and the weakness of safety management contributing to accident can be reflected in the models.

2.1 Railway SMS Regulatory Requirements

Railway as a complex system, engineering an adequate SMS is always a challenging task

(Patacchini 2011). In order to guide the design of the SMS, different scope and depth of the railway SMS requirements are defined by regulators in different countries based on the real operational circumstance and developmental stages. Table 1 provides a list of representative railway standards which enforce the requirements of railway SMS in different parts of the world.

Table 1 SMS Requirements of Railway Safety Standards, Regulations or Guidelines in Different Regions

Name of Standards / Regulations	First Issued Year	Scope
Railway Safety Management System Regulations (Transport Canada, 2001)	2001	Canada
Railway Safety Directive 2004/49/EC (European Union, 2004)	2004	Europe
The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS, 2006)	2006	UK
National Guideline for the Preparation of a Rail Safety Management System (National Transport Commission Australia, 2008)	2008	Australia

In Canada, Transport Canada's Railway SMS Regulations (2001) define the SMS as a formal way to make the operations safely and to establish a safety culture to reduce the railway accidents, which includes safety goals and performance targets, risk assessments, responsibilities, rules and procedures, monitoring and evaluation, and the requirements of documented systems and procedures is enforced in the SMS among the railway companies.

In Europe, European Union defines a railway SMS as "the organisation and arrangements established by an infrastructure manager or a railway undertaking to ensure the safe management of its operations" in the European Union Railway Safety Directive (2004). A related guidance for SMS has published, based on the directive, representing key elements of the SMS in three groups: processes for design and improvement, processes for implementation and operational activities (Patacchini, 2011). For the sake of interoperability demand, UK has introduced the Railways and Other Guided Transport Systems Regulations (ROGS) since 2006, which prescribes a set of requirements for the SMS in mainline and non-mainline rail network. Four main purposes for the railway SMS are identified in the guidance, defining roles and responsibilities to ensure the transport system can run safely, arranging the managers to control the SMS, showing the involvement of workers and their representatives, and making sure the continuously improvement of the operator (ROGS, 2006).

In Australia, National Transport Commission Australia (2008) published the national guidelines to explain the legislative requirements of SMS for rail transport operators contained in the Rail Safety Bill 2006 or Rail Safety Regulations 2006 in Australia, in order to achieve a high level of safety awareness and commitment throughout all parts of the rail transport operator. The guidelines summarise the requirements in the form of the SMS and the content of the SMS determined by legislation and the rail safety regulator, and highlight the mandatory process of safety management plan and the consultation before designing the SMS (National Transport Commission Australia, 2008).

2.2 Basic elements of Railway SMS

There is no complete consensus on the contents of the railway SMS due to the different regulatory authorities in different countries and requirements for different types of operators (Robson et al., 2007), but a reasonable degree of agreement can be achieved on what an SMS must cover (Evans, 2010). According to the official guidance to ROGS in UK (ORR, 2014), with the compliance to the European Railway Safety Directive (Patacchini, 2011), the basic elements of a SMS are:

- Safety policy statement, signed by Chief Executive, shared with all staff.
- Safety targets, for maintaining and improving both qualitative and quantitative safety performance.
- Procedures for meeting standards and other prescriptive conditions and procedures to assure the through life compliance.
- Risk assessments and controlling new risk, managing the change of the operating

conditions or new risks imposed by new equipment.
- Training and skills, to ensure the staff competence.
- Managing the safety-related information within and between organizations through different ways of communication.
- Responding to accidents, incidents, near misses, and other dangerous occurrences, learning from accident to improve the safety management.
- Emergency planning, developing arrangements for responding to emergencies, with the agreement from appropriate public authorities.
- Internal auditing, to review and assess whether SMS is effective.

The contents specified by the regulation or official guidelines primarily provide the fundamental statement of the SMS. From a practical point of view, the detail contents and depth of the SMS should be adapted to fit the size and nature of the business (ROGS, 2006).

2.2 Models of SMS

Since the requirement and importance of SMS in railway are widely recognised and enforced, the question is more about the successful implementation and development of SMS than the adaptation. Great efforts have been done in the industry to produce a comprehensive model of SMS, combined with the requirements and elements for the best practice, which can be used to guide the design, implementation, and assessment of the organisation's management of safety.

European Railway Agency (ERA) adopts a system-based approach to model the SMS based on the process of design, planning, delivery and control of operation (Patacchini, 2011). A tool named 'SMS wheel' (ERA, 2014) is developed as the result, which contains three main parts:

- design and improvement,
- implementation,
- operational activities.

Each of them has a two level classification into more detailed components. Totally 10 principal elements and 32 sub-components are defined in the SMS wheel. The model is available on the ERA's website (ERA, 2014).

In UK, the UK Office of Rail Regulation (ORR, 2011) develops Railway Management Maturity Model (RM^3) to describe an effective safety management, which can be used to examine the SMS. According to RM^3, the key elements of a railway SMS are as followed:

- governance, policy and leadership,
- organising for control and communication,
- securing the co-operation and competence,
- planning and implementing,
- monitoring, audit and review.

These five areas are further divided into 26 items, as seen in Fig. 1, which together can form the criteria and sub-criteria to be reviewed. More detailed description for the criteria can be found in ORR's report (ORR, 2011).

Fig. 1 Railway Management Maturity Model (RM3) (ORR, 2011)

3 Developing a new SMS model

Before we present the new SMS model, first of all, a precondition for evaluation of a SMS is to determine what main elements comprise the SMS. Unavoidably, SMS elements are not completely individual and overlap to some extent. This is also a leading reason that no unified model is agreed across the industry. Taking account of the defined SMS elements from whether regulations (European Union,

2004, ORR, 2014) or industrial models (Patacchini, 2011, ORR, 2011) are either too elementary or too elaborative, we consider to develop an intermediate one.

The existing models often build the SMS model as the process of the management, which allows the SMS elements to be organised from the operational viewpoint. In this paper, SMS elements are organised from an innovated point of view, the management of different aspects. Based on the regulatory requirements from ROGS (ORR, 2014), combined with the most obvious sections of the SMS in the RM3 model (ORR, 2011), the fundamental SMS elements are determined to develop the new model, defined as 'SMS House Model', which can be seen in Fig. 2.

The new model sees the SMS as the management of different objects within the organisation to ensure the safety. Under the top level arrangement through safety policy and safety target, the management of safety is conducted from equipment, information, human and organisational learning, with the compliance of the standards. This model may have deficiencies in representing the process of the management, it offers an innovative way to describe the SMS containing all the basic legal elements (ORR, 2014), however. The detailed descriptions of the SMS elements from this structure are illustrated in Table 2.

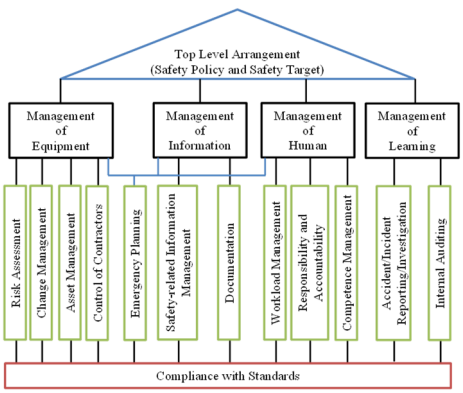

Fig. 2 SMS House Model

The SMS House Model illustrates the SMS like a 'house'. The top level arrangement, safety policy and safety target, is like the 'roof' which covers and protects all the SMS elements in the 'house'. Under the 'roof', the 'house' is divided into four 'rooms', each represents the management of one objects, equipment, human, information and organisational learning. For each particular object, more detailed arrangements are designed, namely the SMS elements. Emergency planning is like the emergency facilities of the 'rooms' that protect the equipment, human and information in the emergency. Under the main structure of the 'house', the 'groundwork' is the compliance with standards, which is the base of the SMS that all the arrangements of safety management should be based on this element. If there is one or two elements fail, minor accidents may appear. When multiple elements fail, serious accidents could occur. The 'roof' and 'groundwork' are the key elements that directly can impact the other parts of the SMS. Therefore, the whole structure clearly describes the SMS as the management of different targets in the organisation.

The strength of the model is its ability to portray the SMS structure visually and to be well-understood. It provides an explicit structure for both the design and review of the SMS. As in this paper, the model can be used to examine the implementation of the SMS by way of reviewing whether there are failures in the management of each object that result in unwanted events. Specifically, accidents can be reviewed to see which SMS elements are involved as the contributory or underlying factors, and further to identify which objects have inadequate safety management.

Normally, failures in elements of SMS can traced back to the weakness in the top level arrangement, in form of safety policy and safety target. Thus, when reviewing the individual SMS elements contributing to adverse events, safety policy and safety target are not included in this paper.

4 Evaluating the new SMS model

In line with the research scope in the UK, Rail Accident Investigation Branch (RAIB, 2014) as UK's independent investigation body for railway accidents and incidents is considered to be the desirable accident database for the study. In spite of the existing of other database, like Safety Management Information System (SMIS) and National Incident Reporting (NIR), most are not fully public and available as the RAIB. The primary aim of RAIB is to improve the railway safety and prevent the potential accidents and

incidents through analysing their causes and circumstances, along with any other contributory or underlying factors that result in the event or aggravate the outcome (RAIB, 2014). Therefore, the accident reports from the RAIB, including accidents, incidents, near misses and other dangerous occurrences, offer the sufficient information for this study.

There are three criteria defined in screening the accident samples.

- Accidents occurred since 2007 and have been fully reported. This is considering the legal requirements of SMS in UK were put into force in late 2006.
- Accidents occurred not due to the third party. This is considering the research scope of the railway domain. RAIB has the classification based on immediate causes with one category of third party, which is helpful for the screening.
- Accidents occurred not simply from the individual human error of technical failure, such as suicide, level crossing misuse, etc. This is considering the research targets of understanding the organisational factors of accidents. RAIB aims at the investigation with potential for significant learning and improvement of safety and, therefore, most are subject to this criterion.

To date, totally 166 accidents, incidents or near misses which occurred since 2007 have completely reports published on RAIB website, among which, nearly 78% of the occurrences are on the heavy rail. Totally 98 heavy rail accidents, 9 light rail accidents, 11 metro meet the another two screening criteria.

Considering the accident pattern may differ from different railway types, the review work starts with the accident samples of heavy rails. Twenty samples of heavy rail accidents are randomly selected based on different immediate causes in order to have more generalised results. Five samples are selected for each for other railway types, which may not reliable in obtaining common patterns due to the limited data, but are available for reference.

After reviewing the whole accident samples, the data are collected to generate the further analysis. A general picture of how SMS is discussed and deemed within the accident investigations can be portrayed. Statistic results can be obtained to reflect the effectiveness of each SMS elements across the industry. The most frequent elements, contributing to adverse events, are regarded as the critical parts of the SMS, and required for further attentions and improvements. The weaknesses that appear together can be perceived, which is of value in the implementation and review/audit of SMS. Finally, the result can also manifest whether each object defined in the SMS House Model is well managed or no.

4.1 Reviewing Accident Reports

Table 3 illustrates the involvement of each SMS elements in contributing to the accident from the sample study, with the summary of the accident samples each element involved and the occurrence rate of elements involved in the accidents. A more clear depiction for the result is shown in Fig 3.

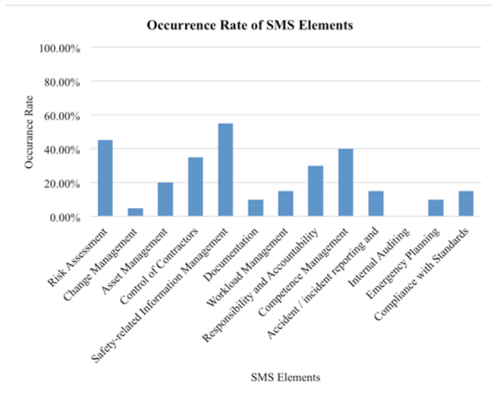

Fig. 3 Occurrence rate of SMS elements

4.1.1 Critical SMS Elements in Accidents

From the result, the most critical SMS elements, most frequently involved in the causes of accidents, are **safety-related information management**, **risk assessment** and **competence management**. They are more likely to be identified as ineffective or inadequate in around half of the accident samples. Besides, control of contractors, and responsibility and accountability are also showing the weakness in around one third accident samples, respectively.

The weaknesses of asset management, workload management, accident/incident reporting and investigation and compliance with standards are all identified three or four times in the accident samples. It is worth noting that although failures in compliance with standards result in three accidents in the sample study,

another three investigation reports mentioned the lack of clear standards or guidance as the contributory factors. As for the industry, it is vital to have appropriate and sufficient standards in place for the purpose of a better SMS practice.

4.1.2 Less Critical SMS Elements in Accidents

According to the above results, documentation, change management and emergency planning are less likely to cause the accidents or exacerbate the consequences, with only one or two involvements in the accident samples. They are considered to be more effective in the management with fewer failures to be identified. It is to be expected that emergency planning will most often be mentioned in very big accidents, since these accidents require a huge amount of resources and services for rescue, involved in multiple organisations. Facing severe accidents, emergency arrangement is easy to be inadequate and unorganised. From the above investigation, the defects in emergency planning are indeed mentioned in the most serious accident, the derailment at Grayrigg. Besides, another incident showed the lack of emergency planning in the evacuation. Emergency planning is primarily for the mitigation of the consequences of the accidents, which is, notwithstanding, less likely to cause the adverse events, the importance is evident in preventing the accidents to have more detrimental effects.

The weakness in internal auditing of SMS does not mentioned in all the sample reports. This is might because of the nature of this element with the purpose of examining the weakness of the whole SMS. Weakness of all other individual components can be deemed as the lack of internal auditing in some ways.

4.1.3 Combining Factors

Most investigation reports have identified the weakness in combining elements as the underlying causes. It can be found that the more severity the accident is, the more combining elements might be. Such as the derailment in Grayrigg, the most serious accident both in the samples and in UK since 2007, has the weakness in nine SMS elements.

Furthermore, weaknesses of some elements are likely to appear together. More than half of involvements of control of contractors are combined with and safety-related information management. Competence management and responsibility and accountability are together in four accidents.

The results from Table 3 and Figure 3 are more apparent to show the combination of the failures in the SMS House Model. The weakness of equipment, human and information management in the accidents are all obvious that each are involved in more than half of the accidents. Organisational learning is both smaller and always overlapping with at least two other things, having less direct influence in the accidents. In particular, 75% of the accidents have the contributory factors from the inadequate management of more than one area. 30% of the accidents involve more than three aspects. One accident is caused by the combination of failures in all four areas in the House Model, which is also the biggest accident in the sample, Grayigg derailment.

These demonstrate the nature of organisational accident that appeared from interacting causes from different levels of the organisation. An exception is human factors. Three out of the twenty accidents had only human factors, and more than half of the accidents with human SMS issues had at most one other category of issue.

4.2 Key Findings

On the basis of the results and analysis above, the initial findings from the review can be summarised as follows.

- Safety-related information management, risk assessment and competence management are the most critical SMS elements which are more frequently failed and lead to adverse events. They indicate the weakness of the railway SMS in implementation.
- Most accidents occurred due to the failures in the safety management of more than one aspect, which indicates the organisational nature of the accidents in the railway that requires the integrated management within the SMS.
- Organisational learning is always combined with other managed areas in the accidents and less directly contributes to the accidents. Considering it has influences on all the areas in the model, it is more appropriate to be part of foundation in the SMS House Model.
- Failure in compliance with standards is appeared occasionally and contributes to the accidents, but a more significant issue in some accidents is the lack of clear standards or industrial guidance, which can give rise to the recurrent accidents across the whole industry.
- Although the requirement of SMS is

different for mainline and non-mainline railways, the pattern of the effectiveness of each SMS components of light rails and metros is similar to that of heavy rails.

- Heritage railways are still lack of formal and adequate SMS, and the need to design the suitable SMS with compliance is urgent.
- Review of the SMS from accidents is more reliable for heavy rails since the accident data is sufficient. In terms of other types of railways, the total number of accidents is limited and the result may not be generalizable, only available for reference here.
- The exact term 'SMS' is rarely used in the accident reports. It might be a defect of the investigation or reporting. A potential reason can be the entire SMS is existed and generally completed in the circumstance of these accidents, and only the direct parts involved from the organisational or managerial viewpoint are considered to be worthwhile to be discussed. This is due to the frequent discussion about the SMS in some accident reports on heritage railways.

Furthermore, we carried out our analysis with additional accident reportThe result of the additional samples is summarised in Table 4 with the comparison between the original samples. The most critical and less critical elements are consistent with some differences. In particular, risk assessment, safety-related information management, and competence management are all identified as the most frequent occurred problems in the two sets. Meanwhile, change management, documentation, workload management, reporting and investigation, and emergency planning are appeared in the original set but not in the additional set.

Table 2 Descriptions of SMS Elements

Managed Object	SMS Elements	Description
Top Level Arrangement	Safety Policy and Safety Target	Setting the top level safety policy and target to provide a clear direction for the organisation to follow.
Equipment	Risk Assessment	Procedures to make sure the potential hazards are identified, with the connected risks are assessed and controlled.
	Change Management	The process to control risks from changes in the existing and new projects in terms of identifying new hazards and taking actions before implementing the change.
	Asset Management	Managing the assets (mostly physical) to achieve effective service delivery and maintenance of associated risks for the strategic and regulatory targets.
	Control of Contractors	The management of the delivery of safe-related supplies and services provided by the suppliers, partners and subcontractors.
Information	Safety-related Information Management	Managing the safety-related information within and between organizations through different ways of communication.
	Documentation	Written SMS and the management of documents
Human	Workload Management	The management of providing the sufficient and right (human and technical) resources to complete the tasks, including a reasonable arrangement to prevent the potential of fatigue and pressure.
	Responsibility and Accountability	A clear distribution of roles and responsibilities, with good management and supervision in place to deliver safe operations.
	Competence Management	Management of training and skills with periodic assessment, to ensure the staff competence.
Organisational Learning	Accident / incident reporting and investigation	Responding to accidents, incidents, near misses, and other dangerous occurrences, learning from accident to improve the safety management.
	Internal Auditing	Periodically reviewing and assessing whether SMS is effective, and identifying the improvements.

Multiple	Emergency Planning	Developing arrangements for responding to emergencies, with the agreement from appropriate public authorities
	Compliance with Standards	Procedures for meeting standards and other prescriptive conditions and procedures to assure the through life compliance.

Table 3 Summary of SMS Elements involved in Selected Accidents

SMS Elements	Involvement in Accidents (Sample ID)	Total	Occurrence Rate
Risk Assessment	01, 04, 05, 07, 09, 13, 14, 18, 20	9	45.00%
Change Management	15	1	5.00%
Asset Management	01, 02, 08, 11	4	20.00%
Control of Contractors	01, 02, 05, 07, 09, 15, 19	7	35.00%
Safety-related Information Management	01, 04, 06, 08, 09, 11, 13, 15, 17,19, 20	11	55.00%
Documentation	03, 18	2	10.00%
Workload Management	01, 05, 16	3	15.00%
Responsibility and Accountability	01, 06, 07, 08, 10, 12	6	30.00%
Competence Management	01, 03, 05, 08, 10, 11, 12, 14	8	40.00%
Accident / incident reporting and investigation	01, 14, 19	3	15.00%
Internal Auditing	/	0	0.00%
Emergency Planning	01, 07	2	10.00%
Compliance with Standards	05, 06, 18	3	15.00%

Table 4 Similarity between Original and Additional accident Samples

SMS Elements	Original Samples S_i	Occurrence Rate R_i	Additional Samples S'_i	Occurrence Rate R'_i
Risk Assessment	9	45.00%	2	40%
Change Management	1	5.00%	0	0%
Asset Management	4	20.00%	2	40%
Control of Contractors	7	35.00%	1	20%

Safety-related Information Management	11	55.00%	3	60%
Documentation	2	10.00%	0	0%
Workload Management	3	15.00%	0	0%
Responsibility and Accountability	6	30.00%	1	20%
Competence Management	8	40.00%	2	40%
Accident / incident reporting and investigation	3	15.00%	0	0%
Internal Auditing	0	0.00%	0	0%
Emergency Planning	2	10.00%	0	0%
Compliance with Standards	3	15.00%	1	20%

5 Conclusions

An innovated SMS House Model is developed to provide the SMS structure from a different point of view, and to determine the fundamental SMS elements to be reviewed. Based on SMS House Model, the overall process of the review is presented, including the criteria for accident screening to obtain the suitable accident data, form for collecting the accident information, and methods to identify the SMS weakness. Considering the different characteristics and circumstance may lead to different patterns, the reviews is conducted separately on heavy rails, light rails, metros and heritage railways.

As the principal finding from the review, safety-related information management, risk assessment and competence management are identified as the most critical SMS elements which are more frequently failed and lead to adverse events. Besides, most accidents manifest the nature of organisational accident with the identification of combing factors in the safety management of equipment, human, information and organisational learning in the House Model.

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