Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

DEVELOPMENT OF A MARITIME SAFETY - TOOL FOR INNER HARBOUR FERRY TRANSPORT OPERATIONS

Carl KERSHAW[1], Karen KLOCKNER[2]

Research article

Abstract: This research was interested in examining if an existing rail industry accident investigation tool could be modified for inner harbour ferry operations. The Contributing Factors Framework (CFF) investigation tool was therefore modified for the maritime industry, specifically as both an investigation tool and a post safety occurrence coding tool. The outcome of this research was the development of a new practical human factors centred investigation tool. It provides a framework for the identification of complex sociotechnical system failures and contributing factors specific to inner harbour ferry operations. The new Contributing Factors Framework-Maritime Safety (CFF-MS) tool fills an existing gap in the need to be able to identify specific inter-relationships between people, technology, and the wider transport system when conducting maritime industry safety investigations.

Keywords: Contributing Factors, Maritime Safety, Investigations, Human Factors, Complex Socio-Technical Systems.

Introduction

The Australian Office of National Rail Safety Regulator (ONRSR) first developed the Contributing Factors Framework (CFF) tool in 2009, with a later edition in 2011 (ONRSR, 2011). The CFF examines the contributing factors to accidents by using three main headings being; Local Conditions and Organisational Factors; Technical Failures and Individual; and Team Actions. Contributing factors of safety occurrences are defined by Grey, Klampfer, Read and Doncaster (2011) as 'any element of an event that, if removed from the sequence of the event could have prevented or reduced the severity of the occurrence'. The CFF tool in the rail industry is sometimes just used as a trend analysis and coding framework, rather than a pure accident investigation tool. However, when used as an investigation tool it offers a simplistic method for gathering data on human factors and specific socio-technical system and technical component failures. Since its inception the CFF has been used as a methodology for understanding patterns of contributing factors to railway safety occurrences via the development of a Safety and Failure Event - Network Model [SAFE-NET] (Klockner and Toft, 2014, 2015, 2018). It has also been developed into a post safety occurrence interview guide for accident investigations within the rail industry (Duncan and Klockner, 2020) known as the Contributing Factors Framework - Interview Guide (CFF-IG). Furthermore, at present a CFF tool is being extensively researched and developed for the trucking (road transport) industry (Delaney et al., 2020) and will be developed into the Contributing Factors Framework - Trucking Industry (CFF-TI).

The research presented here was interested in examining if the rail industry specific CFF tool (ONRSR, 2009) could be adopted into a maritime industry inner harbour ferry CFF investigation tool with the view that would be used by safety practitioners to investigate maritime safety occurrences. It was imagined that the CFF tool, if adapted for this industry, would provide an investigation framework that would give safety practitioners and other stakeholders, investigating ferry safety events, an efficient and cost-effective method to investigate safety occurrences. Importantly this tool would provide detailed information on the contributing factors leading up to maritime ferry accidents that involved human factors, socio-technical systems, and technical component failures.

The extant literature provides numerous examples of how complex system models have been modified and utilised into hybrid investigation tools to identify complicated information and data on maritime accidents. Kee (2017) shows an example where three accident investigation methods were

[1] Central Queensland University, Brisbane Queensland, Australia, kershaw.ca@gmail.com

[2] Central Queensland University, Brisbane Queensland, Australia, k.klockner@cqu.edu.au

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

used to analyse the Sewol Ferry disaster in 2014 by applying Rasmussen's (1997) AcciMap, Leveson's (2004) STAMP and Hollnagel's (2012) FRAM. It is evident from the literature that accident models the Human Factors Analysis and Classification System [HFACS] (2000) and Rasmussen's (1997) AcciMap are being blended with Reason's (1997) model of organisational accidents and latent failure methodology. Celik and Cebi (2009) used HFACS methodology and combined it with Fuzzy Analytical Hierarchy Process (FAHP) in order to identify the role of human errors in shipping accidents. Akyuz (2017) applied a hybrid accident model involving HFACS and Analytical Network Process (ANP) methodology and Akyuz and Celik (2014) combined HFACS and Cognitive mapping (CM) technique in an analysis of a man overboard accident. Wang, Liu, Qin, Huang and Liu (2018) combined Rasmussen's (1997) AcciMap with a social network analysis metric to identify contributory factors in sociotechnical systems. Recent attempts in the rail industry to develop new ways of reviewing how accident phenomenology can be understood, has resulted in research which is focussed on examining safety failure from a more sociotechnical system network view (Huang et al., 2020; Chang et al., 2020) whilst others have developed new statistical tools which allow a deeper analysis of current tools like HFACS (Zhou and Lei, 2020).

However, while many of the models are effective, academically respected, and empirically validated, they are often complex investigation methods particularly for persons untrained in their use and are often not always practical to apply in a specific workplace setting. Perhaps a more practical way for a maritime safety practitioner undergoing a standard near miss or a technical component failure investigation is to have an investigation tool which identifies terminologies and components relating to specific maritime operations. Furthermore, a tool that identifies the human and organisational failures of the specific functions that lead to failure. A tool that ultimately captures the complex interactions relating to maritime ferry social, technical, and organisational systems. Lundberg, Rollenhagen and Hollnagel (2009) describe this principle as 'What-You-Look-For-Is-What-You-Find'. Thus, the inner harbour CFF investigation tool allows the investigator to identify and analyse the very specific areas and contributing factors of an event in ferry operations. Long (2018) argues that investigators must first understand what it is they actually want out of an investigation tool to then be able to apply it effectively. Thus, having the most appropriate tool that has the ability to guide the investigator by way of showing them want to look for is an important factor.

This paper provides an explanation of the evolution of the CFF tool suitable for use in other transport domains, namely the maritime inner harbour ferry operations as well as presenting the final result, being the Contributing Factors Framework-Maritime Safety (CFF-MS) tool. The methodology used included a focus group collaborative approach using technical experts within an Australia inner harbour ferry operation in order to extract and develop the applicability to ferry operations.

The aim of this research was to develop a maritime industry, inner harbour ferry CFF investigation framework tool with two research questions being examined; Could the rail transport industry's (ONRSR, 2009) CFF tool be adopted to maritime transport inner harbour ferry operations? If so, what terminology would be needed in order for the CFF to be specific to inner harbour ferry operations? The result of the research was the develop of a CFF-MS tool with specific technical components and terminologies suitable for maritime transport ferry operations.

The Contributing Factors Framework

Framework Model

The CFF model is based on both James Reason's (2000) Model of Organisational Accidents and Bird and Germain's (1985) Loss Control Model. Reason (1997) suggested that most organisational accidents could be traced back to four failure types which he defined as organisational factors, local workplace factors, unsafe acts and latent conditions. He considered that disparities within an organisation's management systems were the precursors for accidents. Bird and Germain's (1985) sequential model attempted unlike Heinrich's (1931) model to provide more answers to the basic causes of why an accident loss occurred. In their model the first domino was assigned to management through lack of systems, standards and compliance. The next two dominos explained the basic and immediate causation factors. Therefore, the basic causes of an incident event was identified as the people acting in the system and the immediate causes was identified as management oversights. Hence, failure occurred when all these factors aligned to move forward in a sequential order that led to an incident event that ultimately breached each factor's ability to stop loss from occurring. The model recognised both human factor and organisational oversights as being responsible for substandard acts, practices and conditions. The Bird and Germain (1985) model allowed an investigator to analysis the personal factors that resulted in the accident like the lack of knowledge, skill and inadequate training and correlate this information with missing management functions that influenced the event like inadequate equipment or tools.

The ONRSR (2009) CFF model incorporated both aspects of Reason's (2000) and Bird and Germain's (1985) model with the aim of identifying the specific contributing factors that were the causes of accidents and incidents within the rail industry. Figure 1 below shows CFF (2009) model of organisational accidents framework for the categories used in the CFF.

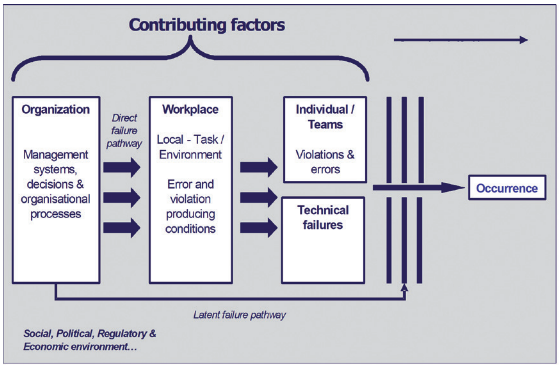

Figure 1. Model of Organisational Accidents (Onrsr.com.au, 2009)

Local Conditions & Organisational Factors

Personal factors*
Knowledge, skills & experience*
Task demands*
Physical environment*
Social environment*
Procedures*
Trainining & assessment*
Equipment, plant & infrastructure *
People management*
Organisational management*
External organisational influences*

Functional area

Freight handling
Infrastructure construction & maintenance
Off-train operations
On-train operations
Passenger management
Rollingstock construction & maintenance

Technical failures

Failed component

Rollingstock
Bogles
Braking systems
Car-body
Coupler/drawgear
Load restraining equipment
On board traction systems
On board train protection systems

Infrastructure
Bridge
Buildings
Cuttings
Drains/flood mitigation systems
Lineside rolling stock fault detection systems
Overhead power systems
Road-rall interfaces
Switches/crossings
Track
Track protection devices
Track support
Tunnels

Signalling & communications
Communication systems
Control interface equipment
Interlocking systems
Traffic control
Train detection systems
Wayside signalling equipment

Failure mechanism

Corrosion
Deformation
Electrical discontinuity
Fracture
Mechanical discontinuity
Software/firmware anomaly
Wear
Other failure mechanism

Failure origin

Design
Manufacture
Installation/commissioning
Operation
Maintenance
Decommissioning
Unknown failure origin

Individual/team actions

Person type

Infrastructure maintainers
Network controllers
Rollingstock maintainers
Train crew
Station staff
Terminal staff
Others persons

Activity type

Preparation & planning
Operating equipment
Communicating
Monitoring & checking
Handover/takeover
Other activity type

Activity type

Error
Violation
Unknown error/violation

Figure 2. Categories and Headings within the Rail Industry (Onrsr.com.au, 2011)

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

The three main categories within the framework of the model consist of Local Conditions and Organisational factors; Technical Failures; and Individual/Team Actions as shown in Figure 2. Within each of those categories were subcategories that enabled contributing factors from within the rail industry to be identified. Thus, the resulting CFF tool was able to identify the specific contributing factors from within the three categories and they could be coded and represented on a database to allow the user to analyse which contributing factors and trends occurred more often than others (Klockner and Toft, 2018).

Usage of Contributing Factors Framework

The benefit of the CFF approach when applying it as an investigation tool is that the model is represented as a visual structured framework that enables a user to systematically extrapolate information relating to organisational, workplace, technical and human error failures. According to Grey et al. (2011) the first category is considered the core of the framework and describes the Local Conditions and Organisational Factors. This category consists of 11 key words which are further describe within a detailed summery section in a second table. This category also highlights a list of 8 functional areas that could be affected by adverse operations which are peculiar to the rail industry. The second category covers Technical Failures, and this section lists headings like failed components, infrastructure, equipment, failure mechanisms and failure origins. There are 5 subheadings included in the technical failures categories. This category is unique as it provides an investigator with an understanding on the mechanisms of failure, for example, wear of an asset or product. It also provides the investigator with a guide for exploring asset failure as it provides a list of the stages of the product's lifecycle. This allows the investigator to identify the exact point of failure within the organisation's technical systems. The third category covers Individual/Team Actions and differentiates between errors and violations. The category shows the different types of roles undertaken in an organisation and this enables the investigator to assess whether actions taken by the system actors were either errors or violations. This category also provides a workplace activity type and lists 5 activity types that could have contributed to the failure that led to an event, for example, an organisation's deficiency in preparation and planning of an activity.

Whilst the main intent of this research was to develop an inner harbour ferry CFF investigation tool it therefore needed to consider potential technical failures relating to ferry infrastructure like vessels, dockyard, vessel repairs, construction, and maintenance of facilities. It was therefore envisioned that out of the three CFF categories, the Technical Failure category would be the most challenging category to adapt because the current components and mechanisms within the rail CFF tool was specific to rail operations.

In addition, for a ferry CFF investigation tool to be successful it must contain specific information that will allow ferry industry stakeholders and investigators to speak the same language with relation to the contributing factors of an incident when analysing adverse events. Grey et al. (2011) argues that a key lesson from the CFF development was that each professional group had its own set of language and meanings. While the words may be the same, it became clear as the work progressed, that meanings could differ significantly (Grey et al., 2011). So, the importance of having an agreed framework that allows for on-going interaction and consultation during an investigation is an added bonus.

A key advantage of using an inner harbour ferry CFF investigation tool is that it can be used in conjunction with other investigation methods. So, the investigator could still apply investigation techniques like Route Cause Analysis, 5-Ways, Fishbone (Ishikawa) and ICAM ™ alongside the CFF investigation tool. But the advantage of the CFF investigation tool is it allows investigators to acquire valuable information on the specific ferry system attributes and deficiencies that can assist in addressing the sources of the problem rather than the symptoms.

Materials and methods

This research was conducted in Sydney, Australian within a company operating passenger inner harbour ferry operations. The chosen method for gaining information that supported or disproved the research questions was through a focus group approach. This method involved identifying participants that had the required skill sets and experience in ferry operations and questioning them to gain their feedback on how a new ferry CFF investigation tool could be developed. Lane, Mc Kenna, Ryan and Fleming (2013) argue that focus groups are an effective way for exploring specific sets of issues. Similarly, McDaniel and Bach (1996) supported this technique as participants can be taken away from their normal environment and placed into social settings that can be moderated by a group leader (the researcher) to generate descriptive or explanatory information.

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

Ethics approval was firstly obtained for the research from Central Queensland University being number 2020-033. Thus, eleven people participated in the focus groups that contributed to the development of the inner harbour CFF investigation tool and they were split into three groups that related to each participants area of expertise. The subject matter experts were assigned to groups relating to either vessel operations; asset management or safety management. Although two of the participants were unable to attend their original scheduled group meetings, alternative arrangements were made, and they were interviewed separately at different times but given access to their original focus group's feedback and then given the opportunity to make additional observations and provide their own feedback to the researcher.

Results

Local Conditions and Organisational Factors

All the members of the focus groups agreed that the eleven items listed in the Local Conditions and Organisational factors heading in the original CFF tool could be adopted to an inner harbour ferry CFF investigation tool within this category. They concluded that the same local conditions were present with in the maritime ferry environment. They also concluded that deficiencies in organisational factors that contributed to accidents such as the lack of management systems, decision making at senior levels and policy setting that guided their operations could be identified by using the eleven sub-categories documented in the CFF. Thus, the focus groups concluded that this category was transferable.

Functional areas

All the focus group participants concluded that this section required changes to the functional area definitions to make it compatible to suit an inner harbour ferry CFF investigation tool. Freight handling which is an area of rail operations that requires the loading and unloading of freight on trains was not considered to be relevant to inner harbour ferry operations, thus the focus groups removed this item.

The heading 'infrastructure construction and maintenance' that related to providing services involving the design, construction and maintenance of rail infrastructure was modified to suite the inner harbour ferry operations. The focus groups differed slightly on their definitions, but they all agreed that changes were required to the headings, and they wanted to separate infrastructure into two parts that included 'vessel construction' and 'infrastructure maintenance and repair'. The focus groups believed this better represented external construction of vessels by a third party and existing vessel repairs undertaken by the organisation in their own dry dock.

Off train operations and on train operations was changed to 'vessel operations' and 'shore operations' as both these terms represented the floating staff, rostering of crews and on shore operations that involved the wharf staff, ferry controllers and vessel and building repair staff.

Passenger management which referred to the area of the rail industry that had responsibility for ensuring the safety of the public and passengers remained relevant to inner harbour ferry operations and was accepted with no change. The focus groups kept this item as it represented maritime ferry functions for embarking and disembarking passengers from the vessels, fixing gangways, security control and crowd control.

Lastly, the item for emergency management was kept as this item was relevant to maritime ferry areas on vessels, wharfs and dry dock and when incident management was required.

Technical Failures

Although the existing railway CFF contained specific railway terminology and components related to rail, the focus groups concluded that the taxonomy of the technical failures category could be adopted into an investigation tool that reflected inner harbour ferry operations. However, the group identified that significant modifications were required to the headings and listed components. Thus, the heading of 'failed components' was changed to 'failed vessel components' but the heading 'infrastructure' was accepted.

But items listed in 'infrastructure' that showed, components and equipment related to rail was replaced by specific pieces of equipment, plant and materials that related to ferry operations. Another heading which was changed was 'signalling and communications' and this was replaced by 'vessel instruments and communications equipment' with vessel instruments and communications devices listed that better reflected maritime ferry operations.

The focus groups determined that the 'failed mechanism' heading only required minor changes to the existing CFF terminology. Thus, the item listed as 'deformation' was changed to 'impact damage' and discontinuity was taken out. The word 'systems' was added to electrical and mechanical, and firmware and anomaly was replaced by IT (information technology).

When the focus groups considered the heading for 'failure origins', they concluded that the existing items captured in the original rail CFF Model was sufficient. The assets management focus group concluded that the CFF had captured all the components required to manage an asset life cycle. Thus, all the groups agreed that design, manufacturing, installation/commissioning, operational, maintenance and decommissioning terminology was transferable into an inner harbour ferry CFF investigation tool.

Individual/Team Actions

The focus groups reviewed the headings of person type, activity type and error/violation type and concluded that these categories did not require changing and could be adopted to an inner harbour

Local Conditions & Organisational Factors	Technical Failure		Individual/team actions
	Failed Vessel Components	**Failure Mechanism**	**Personal type**
Personal factors *	Hull	Corrosion	Operations planners
Knowledge, skills & experience *	Control system	Impact damage	Staff allocation officers
Task demands *	Superstructure	Electrical systems	Operational managers
Physical environment *	Drive line	Mechanical systems	Masters
Social environment *	Vessel alarm systems	Fracture & metal fatigue	Vessel controllers
Procedures *	Bollards/Crucifixes	Software/ IT	Engineers
Training & assessments *	Mooring lines	Wear	General purpose hands
Equipment, plant & infrastructure *	Emergency equipment	Other failure mechanisms	Asset maintenance planners
People management *	Other vessel components	Unknown failure mechanism	Stores controllers & associated procurement
Organisational management *	**Infrastructure**	**Failure origin**	Passengers/customer
External organisational influences *	Vessels	Design	Other persons
Functional area	Dry dock	Manufacture	**Activity type**
Vessel construction and maintenance	Wharfs	Installation/commissioning	Preparation and planning
Infrastructure maintenance and repair	Buildings	Operation	Operating equipment
Vessel operations	Fixed plant & equipment	Maintenance	Controllers/ communication
Shore operations	Mobile plant & equipment	Decommissioning	Monitoring & checking
Passenger management	Bunkering assets & fuel systems	Unknown failure origin	Handover/takeover
Emergency management	Gangways		Other activity type
	Other infrastructure components		**Error/violation type**
	Vessel instruments and communication equipment		Error
	Navigational aids- radar/ lights		Violation
	Maritime thermal imaging systems/FLIR		Unknown error/violation
	Microwave network (CCTV)		
	Automatic identification system (AIS)		
	Global Positioning System (GPS)		
	Depth monitoring		
	Whistle/horn		
	Government radio network (GRN)		
	VHS Radio		
	UHF Radio		
	Public announcement system (PA)		
	Other		

Local conditions and organisational factors	Keywords	
Personal factors *	Alcohol/drugs Expectation Fatigue/alertness Health-related condition Motivation/attitude	Physical limitations Pre-occupation Stress/anxiety Other personal factors
Knowledge, skills and Experience *	Abnormal/emergency operations knowledge and skills Normal operations knowledge and skills	Task experience Communication skills Teamwork skills Other knowledge, skills and experience factors
Task demands *	Distractions High workload Low workload	Time pressure Other task demand factors
Physical environment *	Air quality Housekeeping Lack of environmental cues Lighting/visibility	Noise Temperature/humidity Vibration Weather-related factors Other environmental factors
Social environment *	Diffusion of responsibility Peer pressure Norms and values	Team climate Other social environment factors
Procedures *	Absent procedure Accuracy/adequacy Availability/access	Clarity Work-ability/relevance Other procedures factors
Training and assessment *	Competency assessment Currency tracking Initial training	Ongoing training Training review Other training factors
Equipment, plant and Infrastructure *	Availability Absent equipment, plant and infrastructure Alarm design Control/input device design Display design	Infrastructure design Signage Functionality Reliability Other equipment, plant and infrastructure factors
People management *	Job/task design Selection/recruitment Reward/discipline structures Roles and responsibilities Rostering/scheduling	Fitness for duty monitoring Staff support Supervision Other people management factors
Organisational management *	Business planning and asset/resource management Communication and consultation process Competence of senior personnel Compliance Contractor/interface management Information management	Monitoring, review and validation Organisation design Policy Risk/change management Interface management Other organisational management factors
External organisational Influences *	Community expectations or behaviour Government influences Industry standards or guidance	Regulatory activities Regulatory standards and guidance Other external organisational influences

Figure 3. The Contributing Factors Framework - Maritime Safety (CFF-MS) tool

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

ferry CFF investigation tool. However, the items within the 'person type' heading required changing to specific ferry operation roles. Thus, this section was significantly changed with ten new ferry industry roles added.

The heading that included 'activity type' and listed items of preparation, planning, operational equipment, controllers/communications, monitoring and checking and handover/takeover were all considered as important functions within ferry operations and all accepted. Thus, no changes were made to this section.

The heading for 'error/violation type' defined in the CFF manual as the nature of an identified behaviour from an individual or team action was kept and adopted to the inner harbour ferry CFF investigation tool. The group reflected on how deliberate actions like not following safety rules or procedures can cause accidents but likewise acknowledged that unintended mistakes and human errors can occur and sometimes the actions of people might remain unknown. Thus, they concluded that the items were completely transferable to an inner harbour ferry CFF investigation tool and accepted.

Lastly, the rail CFF was designed with two tables. The first table showed the three CFF main heading categories and the secondly table itemising the key words from the Local Conditions and Organisational Factors category and gave clarification of all the terms that contained an asterisk next to each item. The focus groups reviewed table two and concluded that this content was transferable to an inner harbour ferry investigation tool and accepted the full content of the table.

Figure 3 shows the final CFF-MS model and headings of the CFF being Local Conditions and Organisational Factors; Technical Failures and Individual /Team actions in line with the original CFF (2009) manual.

Figure 3 shows the CFF headings modified for the maritime industry, particularly ferry operations. The tool now provides investigators and others interested in identifying contributing factors to maritime safety occurrences an easy-to-use framework to ensure that all sociotechnical issues are considered.

Discussion

The theoretical foundations of the CFF tool have been proved to be credible when applied within the Australian rail industry and it has been successfully applied to identify the systemic contributors to incidents and accidents (Grey et al., 2011; Read et al,. 2012; Klockner and Toft, 2014, 2015, 2018). The modifications made to the original CFF by the ferry industry focus groups showed that the CFF can be adopted to suit a maritime transport ferry industry application.

In terms of adopting the existing Local Conditions and Organisational Factors category to a maritime ferry investigation tool, the focus groups confirmed Read et al. (2012) theory that certain associations with regards to conditions being present within all workplace and organisational systems proposed by Reason (1990) are accurate. Thus, the items listed like personnel factors, environment, training, management decision making are completely transferable from the rail CFF, and this category was directly applied to the inner harbour ferry investigation tool.

The original CFF category of Technical Failures was significantly adopted to a ferry's operational investigations tool. The focus groups made changes to two of the original headings being 'failed vessel components' and 'vessel instruments and communications equipment', thus adopting it to ferry terminology. But importantly, the focus groups were able to modify the CFF categories with new terminologies, equipment and components relating to ferry technical failures and operations which did not compromise the methodology of the original CFF model. Thus, the new inner harbour ferry CFF technical failures category now allows the investigator to look at the specific ferry operational relationship between component behaviour and system-level outcomes in a non-linear manner. This allows the investigator to identify multiple narratives from different technical perspectives within this category and therefore offers more opportunities to uncover potential emergent property failures.

Use of the CFF-MS

The CFF-MS investigation tool is not a complex method to apply to an accident and incident investigation as the relationship within the CFF categories allows the investigator to understand where organisational, technical, or human failures occurred. Consequently, when an investigator uses this tool to analyse an incident, all the categories, subcategories and listed items within the categories act together to expose a number of different contributing factors. So, with regards to ferry investigations, the CFF-MS investigation tool offers a new method to investigate complex ferry system failures within ferry processes. This is of benefit because each component related to ferry operations is identified and each error type from the behaviour of individuals or teams within the system is exposed. Consequently, the tool allows the investigator to

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

analyse the multiple webs of relationships between the three categories. The investigation tool has the potential to allow the investigator to take a helicopter view of a safety occurrence and allows it to be seen as an unexpected and uncontrolled inter-relationship within the whole system i.e., such as the gaps relating to management oversights, impacts of people and component part failure. Therefore, the CFF-MS investigation tool identifies multiple contributing factors and helps an investigator to systematically consider various reasons for failure rather than just one root cause in isolation.

Limitations

Perhaps the most obvious limitation is that the CFF-MS investigation tool, at the time of writing, has not yet been pragmatically tested and applied to an inner harbour ferry safety occurrence. Therefore, users unfamiliar with the tool might identify more safety factors that are not itemised within the three categorises or do not fall neatly into one of the three categories. The tool also requires an investigator to have a certain amount of local rational on ferry operations as a user is required to interpret specific ferry related information. Likewise, the tool only documents the failure points regarding the actions and decisions taken by people and not their reasons. Thus, it is left to the investigator to examine why an individual or team took a particular decision or course of action.

Recommendations

The practical application of the CFF-MS is now recommended to determine whether the CFF-MS investigation tool adds value to the investigative process within inner harbour ferry operations. Thus, it is recommended that the inner harbour CFF investigation tool be applied to prove its worth. Future researchers may also see worth in developing a CFF-MS industry wide database to identify and code contributing factors related to maritime incidents.

Conclusions

In recent times there has been many different complex investigation techniques being applied to maritime accidents and incidents that require an investigator to have a high degree of skills and resources to be able to acquire the data. Such investigation methods are entirely appropriate but often prove cumbersome and laborious in their use. However, the use of the CFF within the rail industry has proven to provide an excellent tool for examining the socio-technical factors which contribute to rail safety occurrences and was found to be of value for the maritime industry if a similar tool could be developed. This research therefore set forth to develop just such a tool and through the contributions of area experts within the maritime industry the CFF-MS was developed.

The CFF-MS tool has the potential to fill an important gap particularly as it identifies the specific inter-relationships between people, technology and the system components that are connected to ferry operations. The method identifies multiple contributing factors and helps an investigator to systematically consider various reasons for failure. Thus, the CFF-MS tool provides a structured approach for identifying the contributors present in ferry operational systems and also allows for continuous safety improvement as issues are identified. While many of the terminologies and components within the CFF-MS tool are now different from the original CFF rail terminologies, the adaptations have not altered the taxonomy. The CFF-MS tool has the potential to be either applied as a standalone investigation tool or it can be explored in conjunction with other investigation.

In summary, whilst further practical application is required to confirm that the tool is effective the research presented here has proved that the original CFF can be adopted and modified into an investigation tool to suite the maritime transport environment. Persons investigating maritime incidents now have a CFF-MS tool that can improve the quality of investigations as it identifies precise information related to ferry operations. This in turn can help improve investigation skills and outcomes and enhance organisational learning and stakeholder communications by the adoption of a framework that can be discussed by stakeholders using a common language. The CFF-MS tool offers a simplistic method for gathering important information on socio-technical contributing factors to maritime accidents, incidents, and safety related occurrences.

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

References

Akyuz, E. 2017. A maritime accident model to evaluate potential operational causes in cargo ships. Saf. Sci., 92: 17-25.

Akyuz, E., Celik, M. 2014. Utilisation of cognitive map in modelling human error in marine accident analysis and prevention. Saf. Sci., 70: 19-28.

Bird, F.E.J., Germain, G.L. 1985. Practical Loss Control Leadership, International Loss Control Institute, Inc, Loganville, Georgia.

Celik, M., Cebi, S. 2009. Analytical HFACS for investigating human errors in shipping accidents. Accident Analysis and Prevention, 41(1): 66-75.

Chang, L., Dong, W., Yang, J., Sun, X., Xu, X., Xu, X., Zhang, L. 2020. Hybrid belief rule base for regional railway safety assessment with data and knowledge under uncertainty. Information Sciences, 518: 376-95. DOI: 10.1016/j.ins.2019.12.035.

Contributing factors Framework 2009 [online]. Onrsr.com.au, 2009 [cit. 2009-02-01]. Available at: https://www.onrsr.com.au/safety-improvement/contributing-factors-framework.

Contributing Factors Framework version 2 [online]. Onrsr.com.au, 2011 [cit. 2011-08-02]. Available at https://www.onrsr.com.au/safety-improvement/contributing-factors-framework.

Delaney, D., Klockner, K., Toft, Y. 2020. Investigating Road Transport Accidents in Australia: The Development of a Contributing Factors Framework Tool for the Trucking Industry at the Research Presentation Lunch CQUniversity, 2 March 2020 Brisbane.

Duncan, D., Klockner, K. 2020. Development of the Contributing Factors Framework Interview Guide (CFF-IG): All aboard the rail safety truth train. Saf. Sci., 129: 1-8. DOI 10.1016/j.ssci.2020.104853.

Grey, E., Klampfer B., Read, Doncaster, N. 2011. Learning from Accidents: Developing a Contributing Factor Framework (CFF) for the Rail Industry. Conference paper presented at the HFESA 47th Annual Conference, Sydney. Available at: https://www.reserachgate.net/publication/26886667.

Heinrich, H.W. 1931. Industrial Accident Prevention: A scientific approach. New York, McGraw-Hill.

Hollnagel, E. 2012. FRAM, the functional resonance analysis method modelling complex socio-technical systems. Ashgate, England.

Huang, W., Zhang, Y., Zuo, B., Yu, Y., De Dieu, G., Xu, Y. 2020. Using an expanded Safety Failure Event Network to analyze railway dangerous goods transportation system risk-accident. Journal of Loss Prevention in the Process Industries, 65: 1-10. DOI: 10.1016/j.jlp.2020.104122.

Human Factors Analysis and Classification System-HFACS [online]. Commons.erau.edu, 2000 [cit. 2000-02-01]. Available at: https://commons.erau.edu/publication/737.

Kee, D. 2017. Comparison of systemic accident investigation techniques based on Sewol ferry capsizing. JESK, 36(5): 485-494.

Klockner, K., Toft, Y. 2014. Accident Modelling Using Social Network Analysis for Complex Socio-Technical Systems. In Cant (eds): Conferences in Research and Practice in Information Technology (CRPIT).

Klockner, K., Toft, Y. 2015. Accident Modelling of Railway Safety Occurrences: The Safety and Failure Event Network (SAFE-Net) Method. Procedia Manufacturing, 3: 1734 - 1741.

Klockner, K., Toft, Y. 2018. Railway accidents and incidents: complex socio-technical system accident modelling comes of age. Saf. Sci., 110: 59-66.

Lane, P., Mc Kenna, H., Ryan, A.A., Fleming, P. 2013. Focus group methodology. Nurse Researcher, 8(3): 45-59.

Leveson, N. 2004. A new accident model for engineering safer systems. Saf. Sci., 42: 237-270.

Lundberg, C., Rollenhagen, C., Hollnagel, E. 2009. What you look for is what you find: the consequences of underlying accident models in eight accident investigation manuals. Saf. Sci., 47: 1297-1311.

Long, I. 2018. Simplicity in Safety Investigations. Routledge. England.

McDaniel, R., Bach, C. 1996. Focus group research. The question of scientific rigor. Rehabilitation Nursing Research, 5: 53-59.

Rasmussen, J. 1997. Risk management in a dynamic society: a modelling problem. Saf. Sci., 27(2/3): 183-213.

Safety Engineering Series, ISSN 1805-3238 pp. 1-11, DOI 10.35182/tses-2021-0004

Read, G.J.L., Lenne, M. Moss, S.A. 2012. Associations between errors and local conditions/organisational factors in rail incidents and accidents. Accident Analysis and Prevention, 48: 416-422.

Reason, J. 1997. Managing the Risks of Organisational Accidents. Aldershot, Ashgate.

Reason, J. 2000. Human error: models and management. BMJ Quality and Safety, 320: 768-770.

Wang,W., Liua, X., Qinc,Y., Huang, J., Liu, Y. 2018. Assessing contributory factors in potential systemic accidents using AcciMap and integrated fuzzy ISM - MICMAC approach. Int Journal of Industrial Ergonomics, 68: 311-326.

Zhou, J., Lei, Y. 2020. A slim integrated with empirical study and network analysis for human error assessment in the railway driving process. Reliability Engineering and System Safety, 204: 1-12. DOI: 10.1016/j.ress.2020.107148.