

Methodological article

Learning from Accidents: Developing a Contributing Factors Framework (CFF) for the rail industry

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Abstract

Background: In the Australian rail industry, safety performance data are currently collected by accredited rail organisations and delivered to the Rail Safety Regulator of the relevant jurisdiction. These data are gathered using specified criteria which categorise information about rail safety occurrences in terms of ‘what’ occurred. Information regarding ‘why’ the event occurred is not gathered systematically. The rail industry, in seeking to protect itself from the system failures that lead to incidents and accidents, requires rich information about these failures. Key to achieving this is the conduct of systems investigations. The aggregation of data from these investigations can provide valuable information about system-wide safety issues. **Aims:** A national project overseen by the Rail Safety Regulators’ Panel (RSRP) developed a “Contributing Factors Framework” (CFF) to capture information on systemic contributors. **Method:** Human Factors, investigations and rail operations specialists developed the framework based on Reason’s Model of Organisational Accidents. Following road-testing, the framework was released in 2009 with version 2 released in 2011. **Results:** Aggregated CFF data can be used to direct efforts to improve safety in organisations. Other benefits include improved investigation skills and outcomes, a structured and standard frame of reference for discussing investigation outcomes and enhanced organisational learning and communication by adopting the framework’s common language. **Conclusions:** The CFF has been well received in the industry and is in use by regulators, rail companies and investigators. It is being monitored in a review process. An overview of the framework is provided. Issues in terms of the balance between science and practice are discussed.

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Background

Within the Australian rail industry, safety performance data are currently collected by accredited rail organisations and delivered to the Rail Safety Regulator in each jurisdiction. These safety performance data are gathered using criteria specified within a standard (ON-S1 Version 2 and OC-G1 Version 1 [1]). The standard categorises rail safety occurrences in terms of ‘what’ occurred (e.g. derailment on running line), but does not capture information regarding ‘why’ the event occurred.

It is now well accepted that many rail safety occurrences are ‘system accidents’ which originate in the organisational and industrial system. In order for rail organisations to avoid future system failures, they require rich information about the various operational and organisational characteristics that contribute to occurrences. A key mechanism for acquiring this information is the conduct of systemic investigations. These investigations provide valuable information about specific system attributes and deficiencies that can assist in addressing the sources of problems rather than symptoms. However, there has been no consistent framework to code the outputs of these investigations.

A national project overseen by the RSRP and supported by the Australian Transport Safety Bureau (ATSB) developed

a “Contributing Factors Framework” (CFF) which captures information on systemic contributors to incidents and accidents. The aim of the CFF project was to provide regulators, rail operators, and investigators with a useful tool for capturing and aggregating information about contributing factors. Contributing factors can be considered to be “any element of an event that, if removed from the sequence of the events leading to the occurrence, could have prevented the occurrence or reduced the severity of the consequences of the occurrence” [2]. The framework was designed for the rail industry and has a number of elements that are distinctive of heavy rail. With some modifications, there is potential to use the framework in other industries. The CFF is a coding framework not an investigation method. It is not used for identifying contributing factors or interpreting investigation data. It is designed for use after all the analysis has been conducted and the findings developed. At this time findings are allocated to CFF categories.

Benefits

The CFF provides a structured and consistent approach for aggregating, analysing and discussing the systemic contributors identified through investigation, and offers a basis for learning and continuous improvement.

- **Aggregation.** The aggregation and analysis of systemic data allows users to determine if identified problems are isolated events or recurring issues. Over time, aggregated CFF data may allow the identification and analysis of safety trends. It has some potential to enable comparison of contributing factors across participating organisations and/or jurisdictions.
- **Learning.** The CFF enhances the opportunity for organisational and industry learning to occur through a shared language provided by a common set of terms.
- **Investigation quality.** The CFF will encourage improvement to systemic investigation skills through: an improved understanding of contributing factors in systemic failures, and improved description of contributing factors in investigation reports.

Method

A working group reporting to the RSRP was established. Its role was to develop, test and implement the CFF.

The working group

Specialists from rail safety regulators, rail operators and investigations bodies with backgrounds in Human Factors, systemic investigation and rail operations worked collaboratively to develop and test the framework.

Target users

The CFF is aimed at rail industry personnel from a range of backgrounds including:

- Regulators
- Investigators
- Human Factors, risk and safety specialists
- Researchers.
- Rail operations staff and managers with responsibility for safety who may use the analysed data.

Ideally, the original investigator should complete the CFF coding. The framework is designed for use by coders with a range of expertise and knowledge about system safety, Human Factors, investigation approaches and rail operations. However it is expected that coders will not be experts in all areas.

Theoretical foundations

The CFF is broadly based on Reason's [3,4] Model of Organisational Accidents, as it is widely accepted and used within the Australian rail industry. For example, many organisations use AS4292.7 [2], the Investigations Code of Practice [5] and/or the ICAM™ investigations approach [6]. The Reason model has high face validity and is relatively accessible. The CFF was also designed as far as possible to be consistent with other systemic models, so that any systemic investigation could be coded. There are a number of benefits to using a model as the foundation for a coding framework. Models allow causes and their relationships to be better understood, if there is an organising principle to guide

learning [7]. They help structure enquiry, discussion and debate around a common set of elements and relationships, thus supporting discourse, improvements and changes to the model.

Development

The CFF working group considered relevant literature and frameworks that it had access to or subject matter knowledge of (e.g. the ATSB's framework [8] and the Human Factors Analysis and Classification System (HFACS) [9]). A set of codes was developed using these models, with reference to investigation reports and the developers experience. The codes, their descriptions and examples were developed iteratively and applied to case studies. Design goals were developed for the CFF with reference to Shorrock [10] and the expertise of the working group. These goals included: reliability, mutual exclusivity and collective exhaustiveness (MECE), face validity, stability, diagnosticity, flexibility, usefulness, resource efficiency and ease of use. A future goal will be to gauge the validity of the aggregate data against the stated aim of providing sound information about system safety solutions.

Testing

After the draft framework was developed, it was trialled to identify any issues in its application by practitioners. Road-testing was conducted by members of the CFF working group and their organisations, interested rail companies, and investigations bodies. The findings of the road-testing were reviewed and changes implemented. The framework was first published in 2009. A one-year review process led to the publication of Version 2 in 2011 [11].

Results

The outcome of the process was the development of a multi-faceted framework.

CFF data sets

There are three main data sets within the CFF. The first, considered the core of the framework, describes the contributing organisational and local workplace factors. It consists of 11 categories and a set of key words that further describe each item. The second data set covers individual and team actions, which differentiates between errors and violations.

In the initial stages of development, it was found that the existing occurrence classification criteria, ON-S1 Version 2 and OC-G1 Version 1 [1], did not completely cover all relevant aspects of an occurrence. It was considered necessary therefore, that the CFF include technical failures alongside human errors. They are included within the CFF to ensure this essential information is not lost and that there is a complete set of information about an occurrence. The third data set covers technical failures describing the component that failed. Table 1 provides a summary of the 11 core CFF factors. Provision was also made in the CFF to identify absent and failed defences.

Table 1. 11 core organisational factors and local workplace conditions of the CFF.

Organisational factors & Local conditions
• Personal factors
• Knowledge, skills & experience
• Task demands
• Physical environment
• Social environment
• Procedures
• Training & assessment
• Equipment, plant, infrastructure
• People management
• Organisational management
• External organisational influences

Related information types were developed to collect important contextual information about an occurrence as follows:

- **Organisation factors and local conditions.** The functional area affected (e.g. on train operations).
- **Individual / team actions.** The person who made the error/ violation (e.g. rollingstock maintainers) and the activity they were undertaking (e.g. preparation and planning).
- **Technical failures.** The mechanism of failure (e.g. wear) and the stage of the lifecycle where the failure occurred (e.g. maintenance).

Table 2 shows an extract from a CFF coding form which illustrates how findings are recorded, coded and how contextual information is used to further describe and codify the information. Event information, such as date

Table 2. Completed CFF coding form illustrating documentation of findings and how it is codified using the CFF

OCCURRENCE DESCRIPTION (ON-S1 and OC-G1 Categories):					
A train and a road-rail vehicle were given permission to be in the same section and subsequently collided.		Date:	[Date]		
		Location:	[Location]		
		Organisation:	[Organisation (add row for each organisation)]		
Occurrence Types: (include all ON-S1 and OC-G1 Categories for events that occurred):					
Occurrence type:		Occurrence category:		Occurrence sub-category:	
Collision		Yard collision		Between trains	
INDIVIDUAL/TEAM ACTIONS:					
Findings/short description	D	Person type	Activity type	Error/violation type	Organisation
Communications between the signaller and controller were ambiguous with respect to the (anticipated) departure time of the train.		Network controllers	Communicating	Error	
The road-rail crew entered the yard without authority. They took tacit authority from the staff to proceed into the yard to the off-track point.		Train crew	Monitoring and checking	Unknown error/violation	
TECHNICAL FAILURES:					
Findings/short description	D	Failed component	Failure mechanism	Failure origin	Organisation
N/A					
LOCAL CONDITIONS and ORGANISATIONAL FACTORS:					
Findings/short description	D	Local condition/Organisational factor	Keyword	Functional area (affected by the failure)	Organisation
Road-rail crew believed that the staff gave them authority to enter into the yard.		Knowledge, skills and experience	Normal operations knowledge and skills	On-train operations	
Train controller was trying to manage a high workload dealing with operations at the time, including supervising a trainee.		Task demands	High workload	Off-train operations	
Train controller was experiencing some personal issues.		Personal factors	Preoccupation	Off-train operations	

and location, the organisations involved, and the ON-S1 / OC-G1 classification is gathered to enable classification of contributing factors by event type. A procedure for conducting coding using the framework is outlined in the CFF manual.

Discussion and Conclusions

The size and scope of the project led to many insights about the development of coding frameworks and the trade-offs required.

Taxonomy development

The aggregation of data is aimed at pooling information in order to extract meaning that enhances our decision-making ability. To achieve this data must be accurately categorised and its retrieval must be efficient and relatively easy [12]. A tension exists between comprehensiveness and ease of use. Initial development discussions within the working group identified the need to keep the model simple to minimise the likelihood of user error. This requirement was confirmed during the road-testing. The framework was simplified a number of times, however, to ensure that useful data could be gathered, limits to the extent of simplification were agreed. Design goals developed for the CFF appear to have been met to varying degrees.

Reliability. The CFF aims to support consistent application between users and by the same user over time. An inter-rater reliability study [13] using a conservative measure (index of concordance), varied according to the component of the framework being tested. The overall indices for each category ranged between 63% and 73%. It is argued [14,15] that an index of concordance of 70% is acceptable in this context. However, coders participating in this study were inexperienced in using the tool, having received only a short training session on the day of data collection. Read [16,17] reported inter-reliability ratings using the conservative Cohen's kappa using the CFF. Inter-rater reliability was measured for each of five coding pairs, where each independent coder of a pair had identified the same contributing factor. The co-efficients ranged from .47 to .88 which, according to Landis and Koch's [18] categorisation, represents moderate to almost perfect agreement.

Mutual exclusive, collectively exhaustive. As far as possible, CFF categories were designed to be mutually exclusive and collectively exhaustive. This is always difficult to achieve, particularly with organisational categories. However, potential issues are managed by standard definitions and guidance on how they should be applied.

Face validity. The CFF and its outputs should appear valid to people who use it, while sitting comfortably with existing theory and empirical data. Road-testing and training identified that potential users of the CFF are generally accepting of the framework. This may be in large part due to people's knowledge and the accessibility of the Reason model.

Stability. CFF codes should be stable over time with minimal need to change. The core 11 items of the CFF were designed to withstand the need for change. These items have endured across road testing, implementation and the review. Minor

changes to key words and their definitions have been made for clarification, where gaps were identified and continue to be monitored.

Diagnosticity. The CFF is designed to identify the relationships between data items and identify trends.

Flexibility. The CFF should enable different levels of analysis according to need.

Usefulness. The CFF aims to support practical action. Transport Safety Victoria (TSV) has used the CFF to work with a number of rail operators to better understand an event or series of events. It was useful in developing a shared language and understanding of specific occurrences which supported agreement on the relevant safety actions. The framework proved to be a useful method for data collection in a study that considered associations between factors involved in rail safety occurrences [16].

Resource efficiency. Use of the CFF does not place unreasonable demands on time. Currently, training in the CFF takes a half-day. Coding an investigation report that is well written with clearly identified contributing factors may take 20 to 30 minutes. More time is required where investigation reports are extensive or challenging to interpret.

Ease of use. There have been varied reports about the usability of the CFF. Users taking part in the reliability study initially indicated that the model appeared daunting. However, these users indicated that once they had been trained and had used the framework to code a few investigations, they found it easy to use. Other users, perhaps more familiar with the Reason model indicated it was easy to use from first introduction.

A social process

The creation of a taxonomy is fundamentally a social process [19]. While the application of good scientific process is essential, end users must also be allowed to collaborate in terms of creating the definitions and their rules of use. This requires negotiation between disciplines about the purpose of the taxonomy and its definitions and rules.

Learning to speak the same language. A key lessons from the CFF development, is that each professional group has its own set of language and meanings. While the words may be the same, it became clear as the work progressed, that meaning could differ significantly. This illustrates the importance of having an agreed framework, on-going interaction and consultation.

The nature of the data

CFF data is descriptive in nature. The aim of the CFF is to find patterns in the data that are indicative of the state of the organisation or the industry. To do this, there is a need to balance complex tools (involving rich descriptions of incidents and events) with simpler tools that are readily understood and applied [20]. The data collected by the CFF aim to facilitate both, providing a rich picture and quantifiable statistics. It enables the identification of frequencies for each code, enabling reporting of descriptive and other statistical analyses appropriate to categorical data. The free text descriptions associated with each code provide

rich information from the investigation report. The entire CFF record for one event presents the whole story of the event, summarised in a few pages. In itself, this summary is valuable as a reference source about an investigation and its findings.

Quality of investigation report and processes. The quality of an investigation's analysis plays a critical role in determining whether the investigation is successful in enhancing safety [8]. The quality of the data coded using a taxonomy such as the CFF is also heavily dependent on the quality of the investigation. Investigation reports reviewed for the CFF were found to vary widely in quality (where quality is defined as the clear identification of contributing factors to a rail safety occurrence including a chain of evidence that supports the conclusion).

Systemic investigations require analysis of complex sets of data and situations. However the available data can be vague, incomplete and misleading [8]. Further, the outcomes of investigations can be influenced by the backgrounds, experience and judgement of the people doing the investigating. Investigators within the railways come from a range of backgrounds, skills, and experience and many may not conduct investigations as a full time role. This is a practical reality, and it means that the quality of the CFF data is a reflection of the biases, expertise and interests of the investigators. The data has a social context that cannot be ignored in its interpretation.

The working group also found that a coder's own interpretation of the investigation based on their background and experience and can potentially overlay the findings. This is a reason for on-going training and interaction between coders. These concerns may in part explain issues with reliability identified with similar coding systems, such as HFACS [21]. These issues need to be kept in mind when setting boundaries for acceptable use of the CFF and its aggregated data.

Coding and aggregating data

In theory the CFF can be used to code any occurrence where systemic contributors have been found. However, unless a full systemic investigation has been conducted the information gathered will be limited. The validity (i.e. ability to provide useful information) of any coding model rests on it capturing similar data. As such, the CFF working group has set boundaries on coding for the purposes of aggregation at the national level. Coding at this level will be limited to severity level 1 and 2 investigations, as described in AS4292.7 [2]. Therefore, it is more likely that the aggregate data will come from investigations with a similar level of investigative effort, using systemic investigation tools, and conducted by trained investigators. Aggregation becomes less of an issue (a) within an organisation (as regional differences hardly exist and /or processes are fundamentally the same), and (b) where the CFF is being used to develop a shared language and to promote organisational learning.

Benchmarking. Benchmarking involves comparison against other organisations with similar features or processes. The idea of benchmarking is initially appealing, but there is a need to consider what the benefit of benchmarking will be. Is one

organisation safer because it has fewer procedural deficiencies identified in its CFF data, even though it may have more social and environmental factors contributing to its accidents? Benchmarking is also fraught with problems associated with comparability and data needs to be normalised. For example, are the operating conditions and processes of a regional rail operator in Victoria the same as those for an operator in Western Australia? The value of this kind of comparison is limited and is another reason why only certain data should be aggregated at the national level.

Monitoring

Application of the CFF is monitored by the working group to observe how the framework performs over time.

The 'other' category. It has been argued [12] that provision of an 'other' category should be avoided in a completed taxonomy. The danger is that it becomes a catch all for any item that does not self evidently fit elsewhere. Notwithstanding these issues, the working group decided that, in the short term (with rules), this category would be useful to help identify anything important that might have been missed.

Monitoring for 'bucket' categories. Bucket categories are categories that are used frequently and may overwhelm or skew the data. These categories may look like they need to be broken down or renamed. However, the extensive use of a category may also point to biases in the investigation process, or areas where the rail industry as a whole needs to improve. For example, the Organisational management item has within it a range of keywords (Table 3). Investigations coded and analysed by Read [16] showed a high proportion of investigations identifying risk/change management as a contributing factor. The question for analysts to investigate is why is risk/change management so popular? Is it a real effect? Does it originate in investigator bias? Or should there be a change to the category or guidance provided?

Table 3. Organisational factors - Organisation Management (including keywords)

Organisation Management
<ul style="list-style-type: none"> • Business planning & resource management • Communication & consultation process • Competence of senior personnel • Contractor/interface management • Information management • Monitoring/review/validation • Organisational design • Policy • Risk/change management • Other organisation management factors

Error types. The human error and violation category within the CFF has been limited to three codes: Error, Violation, and Unknown. This simple coding approach was adopted because it became clear during testing that any more detailed categorisation was problematic due to issues of complexity. While human error is often mentioned in investigation reports, in those reviewed for the development of the CFF it is rarely described in such a way as to allow useful coding. Since

the human error category is complemented with information about the activity being conducted (i.e monitoring, operating equipment) this level of information could still prove useful. This data set will be monitored to ascertain whether it provides useful intelligence. A future version of the CFF may include a more extensive human error coding system.

Current and future use of the CFF

While the framework is primarily focussed on heavy rail, it is currently being reviewed to ensure that light rail occurrences can also be coded. There has been limited application of the core framework (ie. the organisational and local factors) to maritime and bus accidents in Victoria. The framework is currently in use by Australian regulators, rail companies and investigations bodies and will continue to be monitored by the working group.

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