

**A STUDY OF THE ROLE OF HUMAN FACTORS IN  
RAILWAY OCCURRENCES AND POSSIBLE  
MITIGATION STRATEGIES**

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**Conducted in Support of the  
Railway Safety Act Review**

**by**

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## EXECUTIVE SUMMARY

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The Minister of Transport, Infrastructure and Communities initiated a review of the *Railway Safety Act* to further improve railway safety in Canada and promote a safety culture within the railway industry. A *Railway Safety Act* Advisory Panel (RSA Panel) was appointed to help him in conducting the review and to provide him with findings and recommendations to improve railway safety. In support of their task, the Advisory Panel undertook a series of independent studies.

The objective of this study was to provide a description of role that human factors play in railway train operation, grade crossing, pedestrian and trespassing accidents and incidents, and to examine the effectiveness of the mitigation strategies currently in use by the railway industry. The objective was achieved by:

- reviewing legislation, regulations and related documents;
- conducting interviews with individuals within the Transportation Safety Board (TSB) of Canada, Transport Canada and the rail industry and unions;
- analyzing occurrence data and occurrence reports, and
- assessing current industry practices and regulatory standards influencing the identified human factors related cause factors.

The study has identified a number of shortcomings related to data collection and sharing, and the mitigation of causal factors related to human factors. Several high-level recommendations have been provided addressing deficiencies in the following areas:

- Data Reporting and Sharing Requirements
- TC Rail Safety Competencies Related to Human Factors
- Human Factors and System Design
- Work/Rest Rules
- Crew Resource Management Training
- Changing the Culture
- The Safety Spectrum
- The RSA

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# 1. INTRODUCTION

## Background

Since the *Railway Safety Act* came into effect in January 1989, changes have occurred in the railway industry, including an increase in the number of federally regulated railway companies. Since 2002, there has also been an increase in railway accidents and main-track train derailments in Canada. Concerns have been expressed by private citizens and a number of groups including provincial governments, railway employees, aboriginal and environmental groups with respect to railway safety in Canada. In addition, Transport Canada officials have identified deficiencies with the *Act* during their day-to-day administration of legislative provisions.

Although Transport Canada has taken significant safety enforcement action across Canada over the past years to address these problems, there is a view that the current regulatory framework does not provide the full set of tools to effectively deal with them. There is also a view that the current framework needs to be modernized and better aligned with safety legislation in place for other modes of transport in Canada.

Accordingly, in December 2006, the government announced the *Railway Safety Act* Review to further improve railway safety in Canada and promote a safety culture within the railway industry while preserving and strengthening the vital role this industry plays in the Canadian economy. A *Railway Safety Act* Advisory Panel (RSA Panel) has been appointed by the Minister of Transport, Infrastructure and Communities to help him in conducting the review and to provide him with findings and recommendations to improve railway safety, including possible amendments to the *Railway Safety Act*.

The Advisory Panel has been asked to conduct independent study and analysis, undertake consultations, and prepare findings and recommendations. The Panel has identified a number of issues for study to support its work.

## Objective

The objective of this study was to provide:

- a description of role that human factors play in railway train operation accidents and incidents,
- an examination of the effectiveness of the mitigation strategies currently in use by the railway industry,

- a brief assessment of the current legislative criteria that outlines the minimum requirements for safe train operations such as the Canadian Rail Operating Rules and Work Rest Rules,
- a description of the role that human factors can play in railway grade crossing, pedestrian and trespassing accidents,
- a description and assessment of the current crossing protection systems, and
- an assessment of the current legislation requirements for warning systems timing, sightlines etc. from a human factors perspective.

## **Method**

The objective was achieved by:

- reviewing legislation, regulations and related documents;
- conducting interviews with individuals within the Transportation Safety Board (TSB) of Canada, Transport Canada and the rail industry and unions
- analyzing occurrence data and occurrence reports, and
- assessing current industry practices and regulatory standards influencing the identified human factors related cause factors.

## **Report Structure**

The remainder of the report is structured as follows:

Section 2 presents a discussion of some of the challenges encountered in conducting the research including a presentation of conceptual frameworks that will allow us to place human factors in context of accident causation.

Section 3 presents a discussion of the role of human factors in rail occurrences, and details which factors have been found empirically to be of concern.

Section 4 discusses how human factors found to be causally related to rail occurrences are being managed, and provides an option for a systemic approach towards improvement.

Section 5 provides recommendations.

## **2. CHALLENGES AND OPPORTUNITIES**

### **Background**

In conducting this study, some significant challenges were encountered. Some were anticipated, given the nature of the work; others came as surprises. At least some of the challenges, if addressed systematically, represent opportunities to improve the ability of both regulators and industry safety managers to carry out their responsibilities.

### **Data**

Occurrence data are clearly critically important to ensure that any analysis is data-driven, objective and empirically relevant. Given that Canada has a specific organization (the TSB) that has the exclusive authority for determining cause, data availability should not be a problem. For example, in determining which human factors are more frequent contributors to rail occurrences, one could reasonably expect that a quick search of the approximately 30,000 occurrences records in TSB's Rail Occurrence Data System (RODS) would be all that is required. Unfortunately, there appears to have been a significant reduction in the propensity to record information related to causal factors in the occurrence database record in recent years, especially those related to human factors. This is possibly related to the level of effort associated with this activity, and resourcing issues.

The TSB formally investigates less than 2 % of the 1370<sup>1</sup> rail occurrences reported annually to it. This calls into question the veracity of the causal factors that are reported for those occurrences not investigated by the TSB. With respect to crossing, pedestrian and trespasser-related occurrences, the data issue is especially pronounced, in that these occurrences form a very small proportion of those that the TSB investigates (some notable exceptions notwithstanding).

The impact on this study was to significantly increase the workload associated with data analysis, given that most of it had to be done "manually". Perhaps more importantly, the negative impact on the ability of safety change agents/safety managers to make data-driven, strategic decisions should not be discounted. Given the importance of these issues, the following comments related to data are offered.

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<sup>1</sup> Five year average; 2001 - 2005

### **What are Occurrence Data?**

In general terms, occurrence data are data that relate to incidents and accidents defined as being of interest. In TSB terms, occurrence data are data that relate to incidents and accidents as defined in the TSB Act and Regulation, as well as data that relate to occurrences that do not meet the TSB requirements, but are reported on a voluntary basis. reportable

It should be noted that the TSB's restrictive definition of reportable occurrences have a profound impact on the ability of other agencies to conduct safety analysis. Restrictive definitions are typically developed for simple expediency (the cost of collecting all information is more that the reporting system could bear) or as expressions of limited professional interest. For example, a physician may wish to capture only those data that relate to a particular type of injury or the police may only wish to hear about car accidents that involve injuries or exceed a threshold value. Through its definition of occurrence, the TSB attempts to capture information that will support its goal of identifying safety deficiency in the transportation system.

Whatever the driving force behind the particular definition utilized in a reporting system, the specific limitations of that definition with respect to the effectiveness of the reporting and database system must be acknowledged and deemed acceptable within the aims of the system. This notion is an important element in recognizing that a reporting system and its database is a means to an end, not an end in itself.

### **What is Collected?**

While there are various options available for obtaining preliminary data on occurrences, the TSB generally requires that crew, operators, or company officials involved in the occurrence report it to the TSB<sup>2</sup>. The regulations also specify what data are to be reported regarding the reportable occurrence. This information can generally be viewed as being of the when, where, what, and who variety. (Note that this is not to say that significant effort is sometimes not expended by the TSB in following up on missing data, or confirming the accuracy of reported data.) All other preliminary data are gathered by TSB staff. For example, the information required to be reported for rail occurrences would fill approximately 17 fields of the Rail Occurrence Data System (RODS) database. However, depending on the type of occurrence, there can be a minimum of 40 mandatory fields required of the database. The difference between what is required to be reported to the TSB and the minimum number of mandatory fields is realized by activities that can be viewed as investigation-related. It should be noted that if an occurrence is investigated as a class 2 or 3 occurrence, many more data fields can be populated.

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<sup>2</sup> See TSB Regulations 3.1, 4.1, 5.1 and 6.1

In determining if what is collect is adequate to the needs, the following should be considered:

- "Data held for any purpose or purposes shall be adequate, relevant and not excessive in relation to that purpose or those purposes"<sup>3</sup>, and
- A central tenet of a systems approach to the design of a data system (or any part of it) is that there will be little point in collecting comprehensive data if the system's aims have not been clearly defined, or the proper resources are not available to support the system, including those required for the implementation of resultant countermeasures. Fundamental considerations should centre around whether there is a problem to solve, and if so, what information is needed to solve that problem.

#### **Why Collect Occurrence Data?**

There are several apparent reasons why the TSB collects and retains occurrence data:

- to support TSB managers as they make occurrence classification assessments;
- to store data gathered during investigations,
- to facilitate the identification of safety deficiencies,
- to provide safety data to primary safety change agents (e.g. rail-related industries)
- to provide occurrence information to the public,
- to meet the requirements of external agreements (IMO, ICAO, TC)

With respect to the first purpose, data are required for the occurrence assessment, starting with - "is more information required/is this worth pursuing a bit more, or just case-close it?", then "should someone be deployed?", then "should an investigation be initiated?", then "at what level (minor or major)?"

With respect to the need to store data gathered during investigations, the databases have been designed (and recently re-designed) to facilitate data entry, extraction and analysis related to individual occurrences. This is done by a combination of data fields, (sometimes mandatory or conditionally mandatory), pick lists, and free text boxes. Parts of the database structure, in particular, the "Acts/Conditions" modules, also fulfill a recommended characteristic of an effective database, namely that the occurrence data should shed light on the process by which the accident occurred. Note that investigation records (accounting for approximately 2% of the occurrence records), largely external to

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<sup>3</sup> Data Protection Act, United Kingdom

RODS, also contribute to the third purpose - that of facilitating the identification of safety deficiencies.

With respect the third purpose, data are required to assess problem size and characteristics, to establish trends, and to decide between and evaluate risk control options. A reporting system can provide a bank of data sufficient to establish broad accident categories and provide detailed information on accident causation.

#### **Are The Right Data Being Collected?**

The question of how much and what sort of data is sufficient for the stated purposes is a tricky one. To date, the TSB has not carried out an analysis as to the level of concordance between the data reporting requirements as specified in its regulations and the data required to meet the first purpose, i.e. to support TSB managers as they make occurrence classification assessments. That is, it is not clear to what extent the TSB reporting requirements support managers as they make these assessments, and how much more data must managers or investigators gather to achieve this purpose. It *is* clear that no particular attention has been paid to collecting data that would support Transport Canada in its management of an effective safety management system.

With respect to identifying safety deficiencies, as an example, it is noted in the TSB's Macro Analysis Division Concept of Operations "... it is impossible, while designing a database, to anticipate every type of data analysis that might be required in the future, (therefore) it is to be anticipated that any database will be lacking with respect to its ability to support macro analysis projects. The implication of this is that for most macro analysis projects, it should be anticipated that some data collection will be required."

Further, TSB does not yet have its full complement of staff who will be engaged in macro analysis, nor a recent history of macro analyses. Therefore is difficult to assess the suitability of the data, in terms of availability, structure, quality, etc., as it now stands.

#### **Requirement for a Common Database**

The TSB has a requirement to retain a certain degree of "independence" and as well as providing the protection required of the Privacy Act for the sensitive information it collects. Notwithstanding, the vast majority of the database fields of RODS is being shared with TC through a data exchange protocol whereby TC has access to the data "outside the firewall", those data being up-dated nightly. The major players in the rail industry (RAC, VIA Rail, CPR, and CN) also have access to much of the TSB data through a web-based query tool. As such, a de-facto common data base, or at least the mechanics for one, exists. A critical next could be a consultative process by which safety management related database

requirements, in addition to those of the primary user (the TSB), would be developed.

### **Intelligence<sup>4</sup>**

There is a very limited amount of analysis available to transform occurrence data into insightful information. There is, however, a dearth of comment available founded on “common sense”, which while sometimes sounding compelling, represents a poor basis for analysis. Further, much of the analyses available are not from independent sources, and suffer from poor conceptual frameworks of human error and accident causation.

### **Conceptual Frameworks for the Human Factor**

Researchers and safety managers have long struggled to “understand” accidents, and the human behaviour associated with them. One of the more pervasive notions is that of the “rotten apple in the barrel” analogy – the one weak link in an otherwise safe operation. Reports that represent this view are often replete with statements using counterfactual logic: “If the operator (train or car) or pedestrian had only ....., then the accident would have been avoided.” Notwithstanding that this notion is well-entrenched in our society, its limitations in terms of progressing safety have been well established. Rather, a more productive focus has been in developing an understanding of how the observed behaviour could have made sense to the person involved, given their understanding of the situational factors associated with the occurrence.

One of the better accepted models of accident causation was proposed by James Reason (1990) to explain how human beings contribute to the breakdown of complex, interactive, and well-guarded systems such as rail transportation systems. In such a system, accidents rarely originate from active failures or unsafe acts made by the front-line operators alone. According to Reason, accidents result from the interaction of a series of flaws, or latent failures, already present in the system. The following represent the various levels and areas where errors can exist, and ultimately have an impact on the likelihood for an occurrence.

- upper management decisions - amongst the latent failures at this level are decisions made by upper management, a transportation organization's corporate managers or regulatory officials. When allocating resources, management has to balance, among other concerns, safety against cost. These objectives can conflict and may result in flawed decisions which will be reflected throughout the system.

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<sup>4</sup> Used in the sense of the gathering or distribution of information

- line management deficiencies - flawed managerial decisions have to be implemented by line management through their standard operating procedures, training programs, and other means. If deficiencies also exist at this level, they will increase the accident potential of those managerial decisions.
- existing pre-conditions - if certain characteristics or pre-conditions, such as an unproductive environment, poorly motivated and/or unhealthy workforce, machines in a poor working state, and poorly-established procedures are present in the system, they will influence the front line operation's actions and become a source of unsafe acts.
- latent failures - flawed decisions at the managerial levels, line management deficiencies, and existing preconditions at the worker level represent the system's latent failures.
- unsafe acts - unsafe acts (errors committed in the presence of an unsafe condition) take many forms and, because of the nature of human error, can never be totally eliminated.
- defences - in a complex and well-guarded system, these latent failures may lie dormant for a long time without having significant impact on safety because very efficient defences allow for a great number of these flaws to be simultaneously present in the system without serious consequences.
- window of opportunity - an accident trajectory occurs when unsafe acts interact with latent failures present in the system and breach all the system defences, thus creating a "Window of Opportunity" for an accident to occur. These unsafe acts, for the most part, have been committed before by the same individuals without consequence because existing conditions at that time did not favour an interaction of all these deficiencies present in the system.

The main value of this model is to provide a framework for a more realistic understanding of how all humans in a system can contribute to the breakdown of complex transportation systems.

It should be noted that in more recent times, this framework has been called into question in terms of its ability to model occurrences in very high reliability operations. Instead, the concept of "Drift Towards Failure" has been expounded (Dekker, 2004). This concept is used to account for the situation in which in the hours, days and years leading up to an accident involving highly reliable organizations, there are no reportworthy failures or noteworthy organizational deficiencies; regulators as well as insiders typically do not see people violating rules, nor do they discover other flaws. That is, accidents, and the drift that

precedes them, are associated with normal people doing normal work in normal organizations - not with "rotten apples" engaging in nefarious activities. The concept also acknowledges that at the heart of trouble lies a conflictual model: organizations that involve safety-critical work are essentially trying to reconcile largely irreconcilable goals - staying safe and staying in business. In addition, drifting into failure is viewed as incremental. That is, accidents do not happen suddenly, nor are they preceded by monumentally bad decisions or bizarrely huge steps away from the ruling norm.

Dekker thereby provides a different view of accident causation, one that may not be well served by the traditional views of the accident triangle.

Rasmussen's Skill-Rule-Knowledge taxonomy offers another useful model for understanding and examining human factors in rail occurrences (Rasmussen, J. 1987). He distinguished between two basic error types; planning failures (mistakes and adaptations/violations) and execution failures (slips and lapses). His taxonomy specifically addresses the types of mental activity or behaviour associated with errors:

#### Skill-Based Behaviour

Skill based behaviours are those that rely on stored routines or motor programs (e.g. habits) that have been learned with practice and which may be accomplished without conscious thought. Errors involving skill-based behaviour often occur when the operator is pre-occupied (perhaps with a problem far removed from the immediate task), when he is fatigued or when favourable, familiar, or comfortable conditions lead him to relax too much. Skill-based errors are not usually committed by novices, since they usually have to think about everything they do. They generally occur to those with experience.

#### Rule-Based Behaviour

Rule based behaviours are those for which a routine or procedure has been learned. They are not stored as patterns of motor activity but as sets of rules and are thus stored in our long term memory. These skills, when actioned, involve both the central decision maker and working memory because they are always actioned at a conscious level. Working memory is clearly involved because an operator must keep track of the appropriate procedure to deal with the situation at hand.

Rule based behaviour errors usually occur by an operator making an initial mis-identification of a problem and engages the wrong procedure entirely. Sometimes he may identify a problem correctly, but apply a procedure may be incorrect (for a number of reasons).

## Knowledge-Based Behaviour

Knowledge based behaviours are those for which no procedure has been established. These require the operator to evaluate information and then use his knowledge and experience to formulate a plan to deal with the situation.

Errors associated with knowledge-based behaviour usually relate to operators being misled by their knowledge and/or experience through their biases (the tendency to apply a certain response regardless of the situation) and heuristics (mental rules of thumb).

The lack of uniformity of conceptual frameworks makes data gathering and data interpretation challenging. One of the first challenges when gathering information (e.g. through interviews) is simply to find out what “camp” the person providing sits in, so as to better understand how best to extract the information they have, or how to interpret it. Notwithstanding, these frameworks are suggestive of the need to reach a better understanding of the role of human intervention at all levels of the transportation system, from the regulator to the operator at the switch.

Rasmussen has provided a way of understanding the cognitive processes that underlie erroneous behaviour on the part of any contributor to an occurrence - at any level in the system.

### **Concepts of Causation - A cautionary note**

Some contemporary scientists make the point that “cause” is not something we find - with or without the help of a conceptual framework (or the error classification system derived from it). Rather, cause is something we construct. “The cause” is simply “that factor” where we stop looking any further - for whatever reason. We may stop looking when our resources are expended, or perhaps when the error classification method in use did not provide any further labels for things to look for.

It is generally accepted that the classification of human errors can help managers and engineers understand and presumably manage ways in which people contribute to system reliability and breakdown. (Dekker, 2005) Unfortunately, error classification and human factors frameworks can work to raise hopes of snappy insights into the reasons for error and suggest that there is a quick safety fix. This situation arises when we fail to distinguish “cause” from “the illusion of explanation” (see Dekker) provided by classification systems that appear to have good face validity, while having highly suspect construct validity. Lawmakers, regulators and industry are recognizing that unfortunately, things often are not as simple as the quick fix would propose. Transportation systems, such as rail, that

pursue multiple competing goals in a resource-constrained, uncertain world have demonstrated themselves to be highly resistant to such quick fixes.

### 3. HUMAN FACTORS IN RAILWAY OCCURRENCES

#### A Definition<sup>5</sup>:

Human factors is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance.

In terms of occurrence investigations, human factors encompass all the behaviour-shaping influences that lead up to the occurrence, no matter how far back in time and place those factors had their influence on the system.

Human factors are involved in the majority of industrial accidents and incidents, an involvement that has been variously stated to comprise 60 to 90 per cent of occurrences. A review of the literature specific to transportation occurrence investigations revealed that human factors have been recognized as primary causal agents in the majority of transportation accidents and incidents (e.g., Wilde and Stinson 1980; McCullough and Hill 1993; O'Hare et al. 1994). This should not be too surprising, since all facets of technological systems involve the human element to some extent in terms of its design, construction, operation, management, maintenance and regulation (Reason 1995). It should not come as a surprise, then, that accidents and incidents, such as transportation occurrences, are rarely the result of a single cause. Rather, they occur as a result of the combination of failures or deficiencies in organizational policy and procedures, human actions and equipment (Cox and Tait 1991). This complexity necessitates that both the proximate and underlying causes, as well as their interrelationships, be considered in investigations. Unfortunately, conventional accident investigation processes tend to stop when a proximate cause is found (Reason 1991).

Of equal importance in terms of the role of human factors in accident causation is the notion that the human factors category has often been a convenient place for cause-related circumstances of occurrences which could not be attributed to a failure of the equipment, facility, service or other component of the system (Fawcett, 1986). As such, human factors is seen by some as the cause factor of last resort. This can be seen in the sequencing of activities in conventional investigation methodologies, where “technical” issues are investigated first, followed by the investigation of human factors issues if that doesn't work (or if time or other resources are available).

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<sup>5</sup> As adopted by the International Ergonomics Association in August 2000

It is very important not to treat the terms human factors and human error as interchangeable in terms of accident causation. As suggested in the discussion of causation (above), human error should not be regarded as a “cause” of an occurrence, but rather as a starting point of an investigation into the human factors underlying the error.

Notwithstanding that the importance of human factors as the primary element in such occurrences has been recognized world-wide by government and industry, there is much to suggest that the effective exploitation of human factors can be described as the last frontier in accident prevention.

### **Operational Accident Causal Factors: The usual (unhelpful) suspects....**

Factors identified in occurrence investigations are highly dependent on the labels applied to factors that offer explanation. The labels themselves are derived from the conceptual framework in use. As such, the labels sometimes include both unsafe conditions and unsafe acts as human (cause) factors. For example, the following is typical of a list of causally-related human factors<sup>6</sup>:

- fatigue
- inattention
- absent or vague communication
- poor judgment
- deliberate rule violations
- technical or operational errors
- actions based on assumptions
- complacency
- lack of teamwork

It is questionable that cause factors expressed as above would give safety managers the level of detail required to make the kind of systemic changes to the system that would adequately address the underlying issues.

The TSB has investigated 111 occurrences since January, 2000<sup>7</sup>. In terms of erroneous actions – but, as discussed, not necessarily the causal human factor - unsafe acts<sup>8</sup> were recorded 51 times for those occurrences. Table 1 lists the unsafe acts, by frequencies, for train operation accidents and incidents (i.e. not grade crossing accidents). The actions in brackets represent how the unsafe act was manifest.

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<sup>6</sup> CPR RSA Review Submission: Safety Demands Continuous Improvement, April 9, 2007

<sup>7</sup> As of 30 July 2007

<sup>8</sup> an error or adaptation that is committed in the presence of a hazard or potential unsafe condition

Table 1. Unsafe Acts Recorded in RODS January 2000 – July 2007

Unsafe Act	Frequency
FAILURE TO PROTECT (handling of switches, point of movement, route)	7
FAILURE TO SECURE	2
FAILURE TO USE EQUIPMENT PROPERLY (braking, powering)	7
IMPROPER LOADING/LIFTING	1
IMPROPER PLACEMENT/POSITION FOR TASK (train marshalling)	7
INADEQUATE/INAPPROPRIATE COMMUNICATIONS (verification)	3
INADEQUATE/INAPPROPRIATE MAINTENANCE OF EQUIPMENT (inadequate or inappropriate inspection, servicing equipment in operation)	2
OPERATING AT IMPROPER SPEED	3
LAP OF AUTHORITY (authority inappropriately cancelled, movement enters restriction without permission, movement passed stop signal)	3
USING DEFECTIVE EQUIPMENT	2
VANDALISM	2

As discussed previously, this list does not represent a list of human factors antecedent to rail operations occurrences. An examination of rail occurrence reports published by the TSB indicates that the following factors have been implicated:

- Training,
- Misuse of technology
- The perception that adaptations (work-arounds) are required or appropriate
- Misunderstanding of system operations
- Poor communications within system
- High workload
- Low workload
- Management decision-making

It is noteworthy that the occurrence record, as maintained by the TSB, does not support the proposition that drugs and/or alcohol contribute to the occurrence statistics in any meaningful way. This is not to say that the running trades have not on occasion been found to test positive for drugs or alcohol following an accident. However drugs and alcohol being identified as a causal factor is exceedingly rare.

Note that the issue is not whether drugs and alcohol represent an unsafe condition in terms of transportation safety. Given the abundance of scientific evidence related to their effects on performance, that premise is beyond useful discourse. The issue relates more to whether the defences currently in place – e.g. training, legislation, policies, procedures, supervision, cultural norms – are sufficient the unsafe condition from becoming a safety deficiency (an unsafe

condition for which the defences are insufficient). As evidenced by the occurrence record, it would appear that that is the case.

Other jurisdictions have had a different history. In 1985 the Federal Railroad Administration adopted regulations addressing the problem of alcohol and drug use among railroad employees. This was the direct result of at least 21 significant train accidents involving alcohol or drug use between 1972 and 1983. The regulations mandate the requirement for random drug and alcohol testing for those in safety critical positions and post-accident toxicological testing.

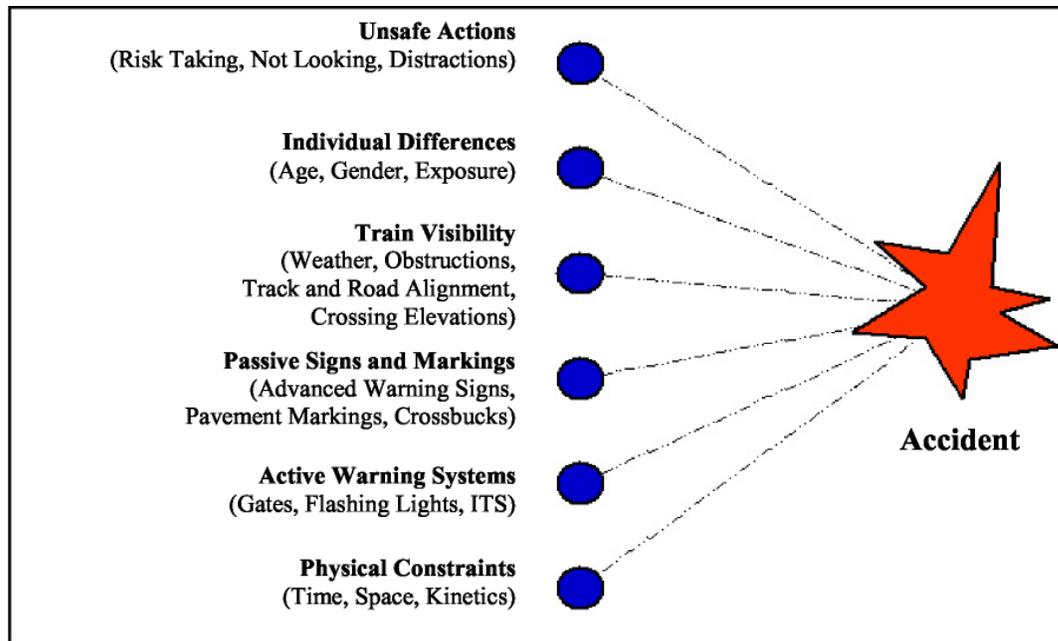
Fatigue, on the other hand, is seen as an important causal factor. That fatigue could play a role in transportation occurrences should not be surprising, given the ubiquitous nature of fatigue in our society. Because of this, the TSB has taken the position that fatigue should be considered a potential underlying factor in virtually all transportation occurrences. However, unlike alcohol or drugs which can be measured by, for example, blood tests, there is no unequivocal physical or chemical test which reports impairment by fatigue. Therefore, establishing the vital link between fatigue and the unsafe acts and decisions that led to the accident is sometimes a challenging proposition. Fatigue has certainly been cited in TSB reports as a causal factor (see Collision CN Rail, London Ont. 16 February, 1995; Collision CP Rail, Greely, BC, 01 October, 1995). Further, a finding associated with a 2003 occurrence noted that “The Work/Rest Rules for Rail Operating Employees permit consecutive hours of wakefulness in excess of 18 hours with no scheduled rest, which increases the risk of fatigue-related errors and accidents”.<sup>9</sup> For another occurrence (R04T0008) the TSB found “The lack of specific measures concerning workload and mental fatigue management for the safety-critical RTC occupation increases the risk that employees will not be sufficiently alert to control trains safely”.

### **Grade Crossing Accident Causal Factors**

With respect to grade crossing accidents in Canada, a comprehensive review was conducted for the Transportation Development Centre of Transport Canada. (Caird *et al*, 2002) The review developed a taxonomy of highway-railway intersection accident contributors to generate hypotheses and deductions about specific cases and common patterns of accident contributors (see Figure 1). Unsafe acts, individual differences, train visibility, passive signs and markings, active warning systems, and physical constraints formed the primary categories of accident contributors. This taxonomy was unique in terms of the available research in that emphasis was placed on multiple contributors to accidents.

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<sup>9</sup> Note that the previous Work/Rest Rules were in force at the time of the occurrence, however the current ones would have permitted the same situation to arise.



**Figure 1** Highway-railway grade crossing accident contributors.

The study found that:

- A number of occurrences revealed multiple accident contributors (more than one action or factor being associated with a single occurrence), thereby providing a more detailed look at how driver behaviour interacts with various conditions to cause an accident.
- Eighty-six narratives indicated an intentional action as a contributing factor to an accident. For behaviours classified as intentional:
  - 35 drivers drove around the gates,
  - 16 drivers attempted to beat the train,
  - 10 stopped or slowed, then proceeded,
  - 4 drove around vehicles stopped or slowing at a crossing (without gates),
  - 4 drove around stopped vehicles and gates.
  - 5 accidents were related to alcohol impairment and
  - 3 accidents were related to fatigue.
- In terms of human factors antecedent to crossing occurrences:
  - 39 TSB reports revealed the possibility of driver distraction as a contributing factor.
  - 12 occurrences involved the driver completely failing to see the train/signals
  - 10 drivers failed to see the train in time to stop.
  - 7 occurrences noted cellular phone use.

- 4 occurrences involved internal distraction (e.g., cognitive processes),
- 3 occurrences involved external distraction (events/objects outside the vehicle),
- 1 occurrence involved the driver adjusting the radio/tape player in the vehicle.

While a complete replication of the Caird study with an updated data set was beyond the scope of this project, a review of the RODS data for January 1999 to July 2007 was conducted. In general, many of the same actions and issues predominate. The most common unsafe acts were:

- Intentionally driving around gate (51)
- Driving through the gate (19)
- Skidded onto track (118)
- Stopped, then proceeded (62)

The following factors were identified as being causally related:

- Environmental factors – including fog, sun glare, wind, night, rain, snow, icy, snow-covered, wet, and driver interactions with them (48)
- Alcohol (14)
- Fatigue (4)
- Attention/Vigilance (67) including Boredom/Monotony (7), Distraction (58)
- Risk Taking 79
- Judgement 21,
- Mental/Emotional State - Suspected Suicidal (15)

In addition, it is noteworthy that the TSB recently issued a recommendation that educational and training material for drivers be reviewed and updated with respect to the risks associated with a heavy vehicle negotiating a public passive railway crossing<sup>10</sup>. The other focus of its recommendation with respect to crossing accidents has been on fatigue<sup>11</sup>:

- R00C0159 Although it could not be determined whether driver fatigue played a role in the accident, the long hours of duty and schedule of the logging truck driver were conducive to fatigue, and thereby increased the risk that his performance could be adversely affected.
- R02W0063 The truck driver had slept for only 30 minutes in the previous 19 hours. It is possible that fatigue affected the truck driver's ability to safely negotiate the crossing.

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<sup>10</sup> TSB Recommendation R04-03 associated with occurrence R02W0063

<sup>11</sup> The TSB has made 6 finding in is rail investigations reports related to fatigue since 2000; 4 of them related to crossing accidents

- R04C0110 Continuous wakefulness, circadian low point, time on task, and the added stress of night driving in thick fog all acted in aggregate to significantly impair the driver's ability to drive.
- R05E0008 The truck driver's physiological condition (hyperglycaemic, fatigued, and dehydrated) was such that it likely impaired his ability to recognize and react to the warning signals and approach of the train.

Extremely few of the approximately 15 pedestrian occurrences per year are the subject of a full TSB investigation. When they are, the finding generally relate to issues of judgement and expectancy. In a second train pedestrian accident that was investigated, visual obstruction, auditory masking, and the attentional abilities of the school age pedestrians serving to limit their awareness such that they were not aware of the approach of the second train were identified as causal. The most common unsafe act listed in RODS relating to pedestrians and trespassers is simply "walked into path of train" (65).

The topic of suicide is frequently raised in the context of vehicular or pedestrian crossing accidents and trespassing accidents. It has been well established that suicide does play a role in such occurrences, however the relative contribution remains of some debate. For example, it has happened that the initial finding of suicide gave way, on balance of probability, to other causal factors. That is, in the case where the locomotive crew reported that they observed the driver/pedestrian look in the direction of the approaching train, and then seemingly drove or walked into the path of the train, it would be tempting to immediately accept a hypothesis of suicide. For some occurrences however, a fuller analysis of all situational factors has indicated that the causal factor was related to human limitations in accurately judging approach speed and distance, especially given the train's size and relatively (to their experience) high speeds. This is not to discount the role of suicide in crossing and trespassing accidents, but simply to point out that the relative contribution of such factors as visual and cognitive limitations are difficult to establish, notwithstanding their salience.

## **4. The Management of Human Factors**

### **Introduction**

The management of human factors that have the potential to be causal factors in rail occurrences takes place at many levels within the rail transportation system, and within many jurisdictions. For example, in the context of managing, and thereby mitigating the causal factors related to crossing and pedestrian accidents, it is clear that the *Railway Safety Act* interacts with provincially managed highway traffic acts. Similarly, the migration system relies on a complicated network of actions on the part of running trade employees, managers, railway police, local police forces and regulators.

### **The *Railway Safety Act* (RSA)**

The objectives of the *RSA* are to

- promote and provide for the safety of the public and personnel, and the protection of property and the environment, in the operation of railways;
- encourage the collaboration and participation of interested parties in improving railway safety;
- recognize the responsibility of railway companies in ensuring the safety of their operations; and
- facilitate a modern, flexible and efficient regulatory scheme that will ensure the continuing enhancement of railway safety.

As such, the objectives would appear to provide the required scope to effectively manage and mitigate the human factors causally related to rail occurrences. It places the onus on the industry to manage safety, In essence, the *RSA* gives railway companies the ability to formulate and submit rules to the Minister for approval (but does not require that such rules be formulated). However, interviews with TC managers, industry and union representatives have indicated that there is a significant degree of concern with respect to the way the *RSA* is structured.

From the TC perspective, the concern appears to be related to the degree to which the department has the “clout” with which to manage safety, combined with the difficulty of measuring an acceptable degree of compliance with the intent of the provisions of the *Act*. For example (with particular regard to mitigating causally-related human factors), it has been pointed out that in exercising Section 19, which provides for a railway company to be required to formulate a new rule or revise an existing one, the response times can be excessively long.

The effective management of safety is then compromised, given the time and effort required to elicit the required change. In addition, Section 20 – whereby the onus is placed on the industry to develop means to manage safety - seemingly leads to the development of operating rules that while of necessity will be compromises between the need to be safe and the need to stay in business, are more commercially-based than scientifically-based. (For example, see the discussion on work/rest rules below). Further, it allows for the articulation of the rule in language that is far more prone to interpretation than had it been written in the language of a departmental legal expert.

It can be posited that the effective implementation of the *Act* is predicated on the regulator having all the competencies required to ensure that the intent of the *Act* is being met. This should include, for example, those competencies required to ensure that the human factors related to accident causation are managed effectively. While there appears to be near uniformity in a strong acceptance for the role of human factors in accident causation within the Branch, there is an equally clear acknowledgement that TC Rail Safety does not have the human resources to meet the requirements of the *Act* in this regard. Not only are there no technically competent personnel on staff, there have been very little in the way of opportunities for the existing staff to receive even introductory training in the domain. It was noted with some irony that the Branch does not even have the resources required to process the contracts that would be needed to engage the technical resources when required.

From an industrial perspective, the *RSA* is seen to be cumbersome, and its application is variable, subject to regional differences (probably due to the regional structure of TC Rail). The *Act* tends to be managed by Transport Canada personnel who are more comfortable in the inspector role than in the required auditor role.

From the union perspective, the *Act* appears to give management considerable leeway in adapting operating procedures to changing commercial exigencies by applying Section 20 or applying for exemptions, but without requiring consultation of the work force. To the extent that labour is consulted in their view, it is usually for minor changes, rather than for the more significant ones.

As a general comment, while the *Act* can be viewed as providing the required mechanisms to effectively manage and mitigate the human factors causally related to rail occurrences, an alternative perspective is possible. That is, it can be interpreted as being founded on, and supporting, a rules-based culture. Historically, both the railways and the regulator have based their safety philosophy on a cornerstone of strict rules compliance. Others, including the TSB<sup>12</sup>, believe that rules compliance is necessary for accident prevention in transportation, but do not accept that rules compliance alone is sufficient to maintain safety in a complex transportation system. The "defence in depth"

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<sup>12</sup> TSB Investigation Report – Edson, Alberta, R96C0172

philosophy advocated by safety specialists for complex systems seeks multiple and diverse lines of defence to mitigate the risks of normal human errors. While the railway industry and the regulator have done much that recognizes the need for such defence in depth, the *Act* as written does not specifically require such an approach.

### **Canadian Railway Operating Rules (CROR)**

The CROR is a compilation of Railway Association of Canada (RAC)-developed and Government approved “rules” that govern and guide employees in the performance of their duties. As a foundational piece of the rail safety management system, they appear to have a significant degree of acceptance from the regulators, industry and unions. For example, the running trade unions reported them to be understandable and comprehensive. As stated above, their main concern is one of lack of consultation when the rules are under review. In their view, they are generally informed about the changes, rather than conferred with as the new rules are developed.

Notwithstanding the comfort level associated with the CROR as a tool to manage safe operations, the scientific literature related to procedures raises concerns about the efficacy of such an approach (reliance on strict rules compliance) as the primary defence against normal human error, and the human factors that are antecedent to them. (see Dekker, 2005) The concerns relate to the sense of (over) confidence that the rules will cover all of the situations that will be encountered and that they actually represent the work required. In addition, the acceptance of the premise that procedures infallibly represent the safest way to carry out a job is seen as problematic. The presence of a violated rule or procedure also provides a common but specious basis for understanding causation – the cause is that a rule was broken. For example, the first “rule” states that “Safety and a willingness to obey the rules is of the first importance in the performance of duty. If in doubt, the safe course must be taken.” In conventional standards of effective procedure development, this would not be seen as a procedure with a particularly high level of potential for being effective.

It can be concluded that the CROR is not always based on human factors research, or modern technological options. For example, it has been pointed out that the rule that deals with the use of the train horn as the train approaches a crossing still is based on the distance of the train from the crossing, rather than relating it to the approach speed of the train, or the performance capabilities of the person to whom the train is intending to give a warning<sup>13</sup>.

A common reaction to occurrences is a call for a higher degree of procedural compliance - extolling the workers to be more diligent in the application of the rules – and then to develop further rules to make the first ones even “clearer”. As regards to managing the risks associated with human factors, a more

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<sup>13</sup> Rule 14 (I) (ii) - At least one-quarter of a mile from every public crossing at grade

progressive approach would be to develop an appropriate understanding of why the rules were not followed in the first place. Such an understanding would provide a much stronger basis for effective mitigation than otherwise.

As stated above, it is acknowledged that the regulators and industry have made, in some cases, significant strides to develop more robust mechanisms to manage human factors and their resultant human errors. However, there are enough indications of the perseverance of the traditional railway rule-based culture to be concerned that this culture will impede the continued development and maintenance of a safe rail transportation system.

### **Work/Rest Rules**

The Work/Rest Rules for Railway Operating Employees (2005) are an example of rules developed pursuant to section 20 (1) of the RSA. They were developed as a collaborative effort between industry management and the unions. The stated goal of the rules (in part) is to meet operating employees' needs and meet the operational needs of the railway companies by providing a flexible approach to fatigue management. They are predicated on the principle that “operating employees have a responsibility to report for work rested and fit for duty”.

The view from at least some industry representatives is that the work/rest rules are workable, especially after a “work-in” period of achieving consensus with the regulator on matters of interpretation. A short line operator reported them to be effective, but noted that in their environment, most work was done on a predictable schedule. A union perspective was that the work/rest rules met their needs, but in any case their collective agreements were sometimes more restrictive.

#### **Summary of Effects of Fatigue on Performance**

A number of key findings relating to fatigue and rest in the occupational setting involving continuous operations have been summarized Rosekind (1995, 1996) and Dinges (1991, 1995)<sup>14</sup>.

- Sleep deprivation results in cognitive performance deficits.
- Disruption of circadian rhythms leads to a decrease in performance.
- Human beings are not very good at estimating their current level of alertness.
- Repeated disruption of sleep schedules can lead to decreased performance.
- Sleep inertia can lead to performance decrements
- Inability to get regular sleep may lead to disruption of the circadian rhythm.

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<sup>14</sup> See also the TSB’s Guide for Investigation for Fatigue.

- Short naps have been found to restore an individual's capacity for performance under certain conditions.
- **Time off alone may not guarantee a rested workforce.** Education, planning, and predictability are needed to maximize utilization of work/rest schedules.
- With repeated loss of sleep a sleep debt builds up over time
- With increased sleep loss and increased sleepiness a person may become vulnerable to performance problems
- Quality of sleep is an important factor. Poor quality sleep can leave a person fatigued and non-restored
- There can be a discrepancy between how people are feeling and how sleepy they are physiologically.
- Scientific evidence suggests that being on an altered shift schedule, like nights, does not lead to an altered internal circadian pattern (one does not adapt fully to shift work).
- Shift workers that go back and forth between shifts experience more difficulties between the circadian rhythms and sleep times.

Further, fatigue produces a variety of performance decrements:

- Performance variability
- Slowed physical and mental reaction time
- Increase in number of work related errors
- Increased tendency to persistently repeat behaviors
- Increase in false responding
- Increases memory errors
- Decreased vigilance
- Reduced motivation and laxity

The magnitude of fatigue effects will vary by individual. While fatigue research provides a variety of measures to illustrate the magnitude of the performance decrements, **one of the more interesting – or alarming – comparison is offered by Dr. Drew Dawson, who demonstrated that the effects on performance of being awake for 18 hours can be equivalent to the effects of a blood alcohol level of 0.05%>**

Note that fatigue is not just a safety issue. Effective fatigue management can have a direct commercial impact as well. A study monitored 55 engineers while operating on two different railroad work schedules. Engineers operated trains in a simulator for a ten-hour shift. The "fast" group had at least an average of 9.3 hours off duty, while the "slow" group had 12 hours off duty. Results showed that the "fast" group got about 4.6 hours of sleep per night compared to 6.1 hours for the "slow" group. Results showed that the "fast" group missed about one third more horns at crossings than did the "slow" group – the safety issue. Furthermore, the "fast" group used about 200 pounds more fuel per trip segment

than did the "slow" group – the economic issue. (Thomas, Raslear, and Kuehn, 1997)

### **Fatigue in Railway Operations**

An oft-cited view is that rail is unique in the world of transportation, in particular because of the reported inability to schedule work assignments in advance. A USDOT/FRA report in 1991 (Pollard, 1991) identified causes of fatigue in an operational rail environment. These are:

- Uncertainty about the time of one's next assignment,
- Excessive working hours,
- Long commutes and waiting times before beginning work,
- Unsatisfactory conditions for sleeping at some terminals,
- The decision not to rest during the day even when subject to call the next night.

Compounding this issue is the fact that most conventional industrial work/rest schedules or regulations lack adherence to the scientific principles relate to fatigue and its management. Typical industrial work/rest rules are based on the following generally accepted, but scientifically invalid, principles:

- All hours of the day are equal and interchangeable
- Fatigue is a function of consecutive hours worked
- Recovery from fatigue is related to hours just worked
- Time spent not working is to be considered, for planning purposes, as rest time

They also tend to rely on the ability of the operator to judge their own level of fatigue, when the research is clear that people are very poor judges of their fatigued state. That is, individuals (especially sleepy individuals) do not reliably estimate their alertness and performance (M. Rosekind et al. 1994).

One recent expert group concluded that five critical factors, based on local and international research, must be addressed in any regulatory approach to fatigue:

- minimum sleep opportunities,
- the cumulative nature of fatigue and sleep loss,
- night-time work,
- work duration, and
- short breaks within working time.

The group proposed a series of recommendations that it argued must be supported by other mechanisms to promote fatigue management, including education, training, road treatments, use of technology and financial incentives and sanctions. Their recommendations include:

- 6 hours minimum continuous sleep in a single 24 hour period
- the 6 hour minimum being adequate for a single day, but not on an ongoing basis
- two nights of unrestricted sleep on a regular basis (preferably weekly)
- one-off trips over 12 hours not to extend into the period between midnight and 6am
- no more than 70 hours working time in a 7 day period
- minimum 15 minute breaks after 5 hours driving (with short breaks totalling 10 percent of working time).

### **Assessment of the Current Rules**

A quick read to the current work/rest rules will identify where there are gaps between its provisions and the principles provided by the current scientific literature. For example, the work/rest rules do not provide for differential maximum work times based on when the hours are worked. Of note, the regulations for flight crew in Canada require a shorter maximum work period if the work is performed at night. Further, as currently written, the work/rest rules allow for a maximum combined on-duty time of 18 hours. Finally, requirements for rest are expressed in terms of “off-duty times”, rather than “minimum continuous sleep” or something that captures that principle.

The rules do require “Fatigue Management Plans” to be implemented by the railway companies. While the guidance provided covers the required elements of an effective fatigue management system, concerns have been raised that the mandated workforce consultation does not take place, and that the plans only have to “filed” with the regulator, thereby effectively depriving the regulator of an oversight role.

At best, the current work/rest rules can be viewed as a compromise between the need to operate in a highly competitive commercial environment (which includes preferences on the part of the labour force with respect to their compensation schemes) and the guidance provided by scientific research. Note that science rarely provides any particular requirements. For example, science supports a maximum blood alcohol level of 0.08%, but scientific literature has data that would support *any* maximum. The maximums selected are typically a policy decision based on risk assessment. Even so, it can be concluded that many fatigue experts would find the current work/rest rules wanting, and unlikely to adequately manage the risks associated with fatigue in rail operations to the extent desirable.

## **Crew Factors**

The conventional defences against the human factors issues related to the running trades are typically thought of as being selection, training and equipment design.

### **Equipment Design**

With respect to equipment design, there is much to suggest that locomotive cab design standards have not kept pace with conventional standards of human factors engineering. Such standards explicitly recognize that human error is a normal event, and require that system be designed “for error”. That is, the design principles would be based on an understanding of cause, and the need to minimize it, and include:

- Making errors visible
- Making errors reversible, and
- Changing attitudes towards error.

Examples of occurrences where design has been found causally related to rail occurrences are not difficult to locate. Issues identified have included the placement and layout of communications equipment in the cab, and the design of cab system displays. For example, TSB Railway Investigation Report R03W0169, examining the October 2003 freight train derailment at Carlstadt, Ontario made a finding that:

“The locomotive radio was inadvertently tuned to the incorrect channel as a result of a keypunch error by the locomotive engineer. The location of the radio in the locomotive likely contributed to the selection of the incorrect channel. Having to reach beyond one's normal range of motion to change channels increases the probability of an error in radio operation.”

In this case, a cab re-designed resulted in the placement of the radio above the front windows of the cab and to the left of the locomotive engineer's chair. This radio location has become the present standard for that locomotives, and makes up a considerable portion of the company's road fleet. The keypad on the radio is operated in the same fashion as a telephone push button keypad. During the course of the investigation, several railway employees indicated that with the number of keypad actions required, it is not uncommon to occasionally select the incorrect channel when operating this type of radio.

To operate the radio, a seated individual of average height is required to stretch beyond their normal range of motion, approximately 6 inches with his left hand or 12 inches with his right hand.

The TSB concluded that having to reach beyond one's normal range of motion to access the radio buttons increases the probability of an error when entering the radio channel.

Another example is found in the location of the TIBS switch where again design issues were identified in the course of the investigation.<sup>15</sup>

There are guidance materials available, which if followed, would reduce safety deficiencies related to design. For example, to supplement the plethora of human factors design guides available, an FRA publication<sup>16</sup> has been developed specifically for application in locomotives. With respect to controls, it advises:

- Place motion controls directly in front of the engineer with the brake module on the left.
- Place the radio hand controls on the left hand side to allow an engineer to operate the locomotive motion controls with his right hand while using the radio with his left hand.
- Controls for the sanders, whistle, horn, headlights, radio and microphone should be located within the zone of reach and preferably within the zone of comfort, if possible.
- Controls should be arranged to minimize engineers changing their position solely to operate a control. Position all controls so that, in manipulating them, operators do not appreciably move their nominal eye reference and possibly miss seeing important events occurring outside or on the principal internal display (Woodson, 1992).
- Controls should be arranged according to the order they are expected to be used. Tracing the sequence of control use will help identify poor arrangements.
- Controls should be consistent with normal limb motions. This means that where arm motions are needed they should be forward and back, not sideways.
- Controls that have a similar function or purpose should be grouped together.

It offers the following advice for error management:

- In managing errors, the first goal is to prevent their occurrence. The system should be designed to prevent the engineer from committing errors wherever possible. For example, in locomotives with AC traction motors, putting the throttle into reverse when it is moving in the forward direction will damage the motors. The system

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<sup>15</sup> TSB Railway Investigation Report R01M0061, Crossing Accident and Derailment, Drummond, New Brunswick, 06 October 2001

<sup>16</sup> Human Factors Guidelines for Locomotive Cabs FRA DOT/FRA/ORD-98/03, Nov. 1998

could prevent this from happening by not allowing the engineer to execute this command when in this condition.

- Where the engineer must engage in operations that are difficult or impossible to undo (e.g., destroying data), the system should notify the engineer and require confirmation before executing the command (Smith and Mosier, 1986).
- Enable the user to recover from errors quickly and easily, (Norman, 1991) when they occur. A responsive system will indicate the nature of the problem and suggest how to correct it.
- Provide an undo function to reverse actions or correct an error. Allow engineers to undo a sequence of commands to change previously entered selections.
- When a command must be re-entered to correct an error, prompt the user to re-enter that portion of the command that needs correction. Do not require the entire command to be reentered.

Further, the call has been made for a human centred approach to railway system design.<sup>17</sup> The "human-centered systems" approach focuses on human capabilities and limitations with respect to human/system interfaces, operations, and system integration. The goal is to design transportation systems that facilitate task completion, so that people can focus on task performance and not be distracted by the technology. This encompasses development of a generation of machines that are adaptable to their human operators, rather than depending on humans to adapt to machines. By incorporating human performance and behaviour principles into the design, development, and operation of transportation systems, it will be possible to improve safety while enhancing system performance, with increases in capacity, operational efficiency, and productivity.

The design of processes and procedures has been cited as well. Concerns related to the crews' ability to effectively and safely handle heavy trains in emergency brake application situations caused the TSB to recommend that "Transport Canada encourage the railway companies to implement technologies and/or methods of train control to assure that in-train forces generated during emergency braking are consistent with safe train operation"<sup>18</sup>.

## **Training**

In the course of this study, training concerns were expressed as well. In particular, reference was made to new training regimes that offer less mentoring and exposure to operational environments than has traditionally been the case.

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<sup>17</sup> See Human-Centered Systems, The Next challenge in Transportation, U.S. Department of Transportation

<sup>18</sup> TSB Recommendation R04-01

In addition, the concern was expressed that locomotive engineers who earn their qualifications in very small short line or yard environments, are being hired directly into much more complicated operational roles by the major carriers<sup>19</sup>.

### **Crew Resource Management**

Crew Resource Management (CRM) was conceived of as a method to change the working culture in the cockpit of commercial airliners following a series of catastrophic aviation accidents. In an aviation context, CRM is the effective utilization of all available resources to ensure the safe completion of flight operations. It has been extensively researched since its inception, and has generally evolved into Line Oriented Flight Training (LOFT). It should be noted that its efficacy in reducing crew error has not achieved universal acceptance amongst human factors professionals. Notwithstanding, it has been cited in TSB Rail investigation report: "The reversed roles of the locomotive engineer and conductor without adequate crew resource management discipline created a work environment leading to the switch being left in the reverse position"<sup>20</sup>.

CRM training addresses the management of attention, operational tasks, stress, attitudes, and risk. Optimizing the management of these will have a direct effect on four factors critical to the successful outcome of any train movement, namely situation awareness, metacognition, shared mental models, and resource management.

- Situation Awareness involves recognizing and defining the nature of the problem encountered and, as such, is the first and most critical step in effective and safe decision-making. Good situation awareness is necessary for recognizing that a decision must be made or an action must be taken;
- Metacognition means "thinking about thinking", and refers to the process of reflecting on and regulating one's own thinking. It involves defining the problem, and deciding what decisions will have to be made, what information and resources are required, and what are available.
- Shared mental models allow for the involvement of others in the problem solving, or the offering of information useful to the safe completion of the movement. Generally, a crew sharing the same mental model will be more likely to be working toward the same ends. The sharing of mental models with resources outside the locomotive cab, through effective communication, such as the RTC and car men will optimize mission effectiveness.

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<sup>19</sup> The validation of these concerns was beyond the scope of this study.

<sup>20</sup> TSB Report R96W0171

- Resource management itself involves an active process of decision-making. It requires an understanding of what must be done and in what priority, and what resources are required and are available. Good resource management, involving all available resources, has the effect of reducing the demands on the locomotive engineer, especially during times of high workload or complex decision-making.

It is recognized by many that there are multiple determinants of mission effectiveness and rail operations safety, such as individual, organizational, and regulatory factors. Concepts inherent in CRM provide practical guidance as to how to optimize these factors. Selection of personnel more predisposed to team activity represents a long-term, but effective, strategy. Management must develop the culture and norms that support a team approach, including role models who practise and reinforce such an approach. Finally, the regulators can provide support by at least encouraging a team approach to mission effectiveness, if not actively supporting CRM training.

It is to be expected that such a notion may generate reasons given to support the assertion that CRM would not be applicable for railway operations:

- We already do it, we just call it something else i.e., Job Briefings.
- CRM training undermines authority.
- CRM is essentially common sense, and you can't train for that.
- CRM may be OK for those Air guys, but our operation is different.
- We have no time or money available for CRM.

These concerns need to be placed in the context of a systems approach to rail safety in order to develop an awareness that CRM training may hold some potential for a positive impact on rail safety. The training, as a minimum, should entail the development of an attitude throughout the full corporate structure that a single crew, operating in a complex environment in a design-deficient environment, may quickly and routinely become task saturated. Only through the appreciation that there are at times more players involved in the task than just the locomotive engineer will occurrences, such as the one referenced above, be avoided. In addition, in keeping with the role of human factors in rail occurrences, consideration should be given to including such as aspects of human factors as the mechanisms of human error and the avoidance of error traps in the training provided to all levels of railway operations and management.

## **Crossing Protection**

It goes without saying that the most effective protection against crossing accidents involving vehicles, pedestrians or trespassers is provided for by separating the grade between the two actors in the transportation system. Given the vast numbers of crossings, and the sparseness of the population surrounding

the majority of them, this is clearly an economically unfeasible solution for all of the cases. There are a number of options available on the continuum between total grade separation and no protection at all, each with varying efficacies and expense. The Caird study of 2002<sup>21</sup> included an assessment of countermeasures available to reduce the frequency and severity of accidents at highway-railway crossings. Table 1 from the Caird report shows the effectiveness and cost of a range of countermeasures.

Countermeasure Type, Effectiveness, Cost and References

<b>Countermeasure</b>	<b>Effectiveness</b>	<b>Cost</b>	<b>Reference(s)</b>
Stop Signs at Passive Crossings	Unknown	\$1.2 to \$2 K (U.S.)	NTSB (1998a)
Intersection Lighting	52% Reduction in Nighttime Accidents over No Lighting	Unknown	Walker & Roberts (1975)
Flashing Lights	64% Reduction in Accidents over Crossbucks Alone; 84% Reduction in Injuries over Crossbucks; 83% Reduction in Deaths over Crossbucks	\$20 to \$30 K (U.S.) in 1988	Schulte (1975) Morrissey (1980)
Lights & Gates (2) + Flashing Lights	88% Reduction in Accidents over Crossbucks Alone; 93% Reduction in Injuries over Crossbucks; 100% Reduction in Deaths over Crossbucks 44% Reduction in Accidents over Flashing Lights	\$150 K (U.S.)	NTSB (1998a) Schulte (1975) Morrissey (1980) Hauer & Persaud (1986)

<sup>21</sup> TP 13938E, A human factors analysis of highway-railway grade crossing accidents in Canada, Cognitive Ergonomics Research Laboratory, 2002

	Alone		
Median Barriers	80% Reduction in Violations over 2-Gate System	\$10 K (U.S.)	Carroll & Haines (2002a)
Long Arm Gates (3/4 of roadway covered)	67 to 84% Reduction in Violations over 2-Gate System	Unknown	Carroll & Haines (2002a)
4-Quadrant Gate Systems	82% Reduction in Violations over 2-Gate System	\$125 K (U.S.) from Standard Gates \$250 K (U.S.) from Passive Crossing	Carroll & Haines (2002a), Hellman & Carroll (2002)
4-Quadrant Gate System + Median Barriers	92% Reduction in Violations over 2-Gate System	\$135 K (U.S.)	Carroll & Haines (2002a)
Crossing Closure	100% Reduction in Violations, Accidents, Injuries and Deaths	\$15 K (U.S.)	Carroll & Haines (2002a) NTSB (1998a)
Photo/Video Enforcement	34 to 94% Reduction in Violations	\$40 to \$70 K per Install (U.S.)	Carroll & Haines (2002b)
In-Vehicle Crossing Safety Advisory Warning Systems (ICSAWS)	Unknown	\$5 to \$10 K (U.S.) per Crossing + \$50 to \$250 (U.S.) for a Receiver	NTSB (1998a)

Notes Countermeasures are listed by approximate date of introduction. The effectiveness of a countermeasure is expressed as a function of the percentage reduction in accidents and other violations over some previous treatment. Cost is expressed in U.S. dollars for the most recent reference.

The results of the study can be summarized as follows:

- Observations of driver behaviour conclude that crossing familiarity and an expectation that a train will not be present have the potential to lull drivers into complacency or poor looking habits. Therefore, automatic warnings that prevent train-vehicle interactions altogether have the greatest potential to reduce accidents, injuries and fatalities<sup>22</sup>.

<sup>22</sup> Investigation reports into pedestrian accidents would support this conclusion

- Stop signs at grade crossings are frequently disregarded by drivers. The effectiveness of stop signs in reducing accidents over existing accident rates has not been established.
- Street lights at crossings have been shown to reduce night time vehicle-train collisions.
- The conversion of passive crossings to active crossings, by using flashing lights and bells and gates, has been shown to substantially reduce accidents.
- Upgrading flashing lights and gates to other countermeasures such as photo-enforcement, median barriers, and four quadrant gates have been shown to reduce the frequency and severity of violation behaviours.
- Supplementary advance warning signs that indicate what drivers should do (e.g. “look for trains” and “do not stop on tracks”) as they approach a crossing should be developed and evaluated. Given that drivers fail to notice advance warning signs, multiple signs should also be considered.
- Intelligent Transportation Systems (a program that adds information and communications technology to transport infrastructure and vehicles) offers an alternative to conventional warning systems (both active and passive) currently used at grade crossings.
- The integration of countermeasures at problem highway-railway grade crossings will contribute to the historical reductions already realized. The reduction of accidents, injuries and fatalities will occur with uncertain variability that will be difficult to attribute to any specific countermeasure program.

It is important to note that technology is not the only approach to providing for safety at grade crossings. Education can be a very effective adjunct to technology, especially for situations where technology is largely absent. In this regard, Operation Lifesaver requires special mention. Operation Lifesaver is a national public education program sponsored by the Railway Association of Canada and Transport Canada and works in co-operation with the Canada Safety Council, provincial safety councils/leagues, railway companies, unions, police, the public and community groups. Its goal is to reduce the needless loss of life, injuries and damages caused by highway/railway crossing collisions and train/pedestrian incidents. It has been providing presentations, public service announcements, posters and the like for 25 years.

Educational initiatives such as Operation Lifesaver will continue to have a vital role in improving crossing safety, however the challenges in terms of developing the appropriate networks and adapting its key messaging as the demographics change will be substantial.

As discussed above, economic feasibility precludes the provision of grade separation at every crossing location. How much safety can be afforded to trains, vehicles and pedestrians is a questions managed by Transport Canada through a risk assessment process. It is noteworthy that the regulator has decided that more work is required to meet the challenge of ensuring the safety of pedestrians at grade crossings. It will soon launch a study whose objective is to:

- Identify and develop engineering countermeasures and functional requirements for grade crossings (including the approach) across Canada in order to improve pedestrian safety;
- develop comprehensive criteria that will be used to identify crossings requiring pedestrian safety treatment;
- develop comprehensive criteria that will be used in determining the most appropriate cost effective pedestrian safety treatment for specific grade crossings.

### **An Alternative Approach to Managing the Human Factor**

It is likely that the impact of human factors on rail safety will continue to frustrate the best efforts of those charged with improving the occurrence rate. Dr. Jim Reason likens most efforts to attack the issues that lead to occurrences to the swatting of mosquitoes – the efforts to do so are noisily apparent, but there are always more to take their place. The more effective approach is to drain the swamp in which they breed – that swamp comprised of such features as poor design, conflicting goals, inadequate training and inadequate defences. Ultimately, Reason would offer that the best approach would be to improve the safety culture of the organization, as the primary motivator for change then becomes an internalized drive for safety at the systems level, rather than the more reactive, localized behaviour. It is hereby suggested that rather than offering a series of fixes for the mitigation of the human factors issues underlying rail-related safety deficiencies, a more productive and progressive approach would be to advocate for an improvement in the culture underlying the management of safety in the rail mode of transportation.

### **Safety Culture**

Safety Culture can be defined as something an organization is - the beliefs, attitudes and values of members regarding the pursuit of safety, and as something an organization has - the structures, practices, controls and policies designed to enhance safety. In perhaps its shortest form, safety culture is simply

“the way things are done around here” (with respect to safety). According to Reason (1997) an effective safety culture is built on five essential elements<sup>23</sup>:

- A Just Culture - an organization has a Just Culture if there is an atmosphere of trust in which people are encouraged for providing essential safety-related information but in which they are also clear about where the line must be drawn between acceptable and unacceptable behaviour.
- A Reporting Culture - an organization has a Reporting Culture if people are prepared to report on their own errors and near-misses. Without such a corporate “memory” the system cannot learn
- A Flexible Culture - an organization has a Flexible Culture if it effectively adapts to changing demands.
- A Learning Culture - an organization has a Learning Culture if it acts on (implements, does, tests) the reforms needed to make the system safer. Both reactive and proactive measures are used to guide continuous and wide-reaching system improvements rather than mere local fixes.
- An Informed Culture - An organization has an Informed Culture if those who manage and operate the system have current knowledge about the human, technical, organizational and environmental factors that determine the safety of the system.

Even a cursory analysis of the Canadian railway environment would lead one to conclude that the elements listed above are not readily apparent in most of the railway companies. Some significant initiatives notwithstanding, the “rules-based” culture has shown remarkable perseverance. Such a culture is typically characterized by a lack of consideration of situational factors, and a focus on a “rules-based” system to “require” the appropriate actions of individuals, especially those closest to the accident scene.

By comparison, aviation, especially in Western Europe and North America, has evolved along a different path. The safety culture typically found in the air mode of transportation may be generally more advanced than rail, but it didn’t get there without a lot of hard lessons along the way. To some extent, aviation initially went down the rule-based concept of operations, but then was “forced” to move into a performance based culture along the way. Flight safety was pushed out of the “pilot error” phrase developed during WWI and the early part of WWII (where the safety problem was largely dealt with if the “bad apple” had the good graces to perish in the accident) by the significant loss of resources due to non-operational accidents, (generally exceeding combat losses). Through research into human

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<sup>23</sup> Managing the Risks of Organizational Accidents.

factors, an understanding of human limitations was developed. With the persistence of a significant accident rate, this later developed into an integration model of “man-machine-mission”, where the human element (both capabilities *and* limitations) was considered while designing and operating the system. The stated aim was to maximize the likelihood of the system meeting its goals. Ultimately, the language of safety culture and its constituent elements has become well ingrained in the air mode of transport. While it is certainly the case that not all aviation companies would be judged as having an effective safety culture, to a greater extent than the rail industry, the benefits of such an approach to the aviation industry are taken as a given.

Reason (1997) suggests that a less-than-adequate safety culture results in:

- an increase in the number of defensive weaknesses due to active failures,
- a reduced ability to appreciate the full extent of the operational dangers, and
- an unwillingness to deal proactively with known deficiencies in the defences-in-depth.

### **The Safety Spectrum**

An article developed by Transport Canada, Civil Aviation and published in the ICAO Journal<sup>24</sup>, suggests that there is a spectrum to safety, and people and organizations can be positioned along this spectrum according to the way they act in reconciling safety, business and management issues. He goes on to explain that inside an organization, it becomes apparent that certain actions are rewarded while others are sanctioned. Managers and employees learn these patterns and conform. This pattern of values, expectations and behaviours becomes the organization’s culture. Certain cultures can advance the cause of safety; while others are counter-productive. The Safety Spectrum attempts to position the range of cultural attributes and associated approaches to safety management. (See Appendix C for a matrix depicting the spectrum.)

The Safety Spectrum brings together current thinking on safety, management, and business issues. It incorporates the safety thinking of James Reason, Charles Perrow and Patrick Hudson; the risk management thinking of A. Ian Glendon and Alan Waring; the business and management thinking of Forest Reinhardt and Joan Magretta; and the regulatory thinking of Malcom K. Sparrow.

The Safety Spectrum also provides a frame of reference for the regulator. Regulators interact with companies and persons according to where they sit on the safety spectrum. Regulators need, therefore, to respond in a fashion appropriate to the behaviours exhibited by the organization or individual. They

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<sup>24</sup> See **The Safety Spectrum**, ICAO Journal, Volume 60, Number 4 (July/August) 2005

must develop appropriate strategies to ensure compliance with the minimum safety standards and provide the right inducements or bridging strategies to advance safety management thinking.

It is suggested that consideration be given to assessing the Safety Spectrum for its efficacy in providing guidance to both the rail industry and regulator.

If interpreted in a particular light, the *Railway Safety Act* can be viewed as providing the required mechanisms to promote an effective safety culture. However, the *Act* as written does not specifically require such an approach, and to date there is little evidence that it has been effective in producing one.

## **5. Recommendations**

### **Data Reporting and Gathering Requirements**

A multi-stakeholder needs analysis should be conducted to define data requirements and develop reporting and data sharing mechanisms to ensure that occurrence-related data can be used by safety managers to their best advantage. Particular attention should be paid to those lagging and leading indicators that will support an effective safety management system and the advancement of a robust safety culture.

### **TC Rail Safety Competencies Related to Human Factors**

TC Rail Safety should significantly increase its capacity to effectively manage human factors related to rail safety. Consideration should be given to hiring technically competent staff, and provide human factors introductory training to existing staff.

### **Human Factors and System Design**

The *RSA* and/or regulations should be amended to require industries to ensure that new equipment conforms with the available guidelines and standards of human factors engineering, and that strategies be developed to mitigate the effects of poor design of existing equipment on safety.

### **Work/Rest Rules**

An independent team of fatigue experts should be engaged to assess the ability of the current work/rest rules to adequately manage the risks associated with fatigue in rail operations. The results of the assessment should be utilized by TC Rail Safety to mandate any changes that might be indicated.

### **Crew Resource Management Training**

Industry should be required to fully assess CRM and the concepts inherent therein with a view to determining the merits of training for, and supporting, such an approach to risk management. TC Rail Safety should be prepared to provide support to such an endeavour. In addition, in keeping with the role of human factors in rail occurrences, consideration should be given to including such as aspects of human factors as the mechanisms of human error and the avoidance of error traps in the training provided to all levels of railway operations and management.

## **Changing the Culture**

TC Rail Safety should initiate a comprehensive change management program designed to improve the culture underlying the management of safety within its own organization and the rail industry in general through the development of the essential elements of an effective safety culture.

## **The Safety Spectrum**

The Safety Spectrum should be assessed for its effectiveness in providing guidance to both the rail industry and regulator.

## **The *RSA***

The *RSA* should be amended to specifically require a “defence in depth” philosophy (i.e. multiple and diverse lines of defence to mitigate the risks of normal human errors), rather than providing tacit support for an exclusively rules-based approach to safety management.

The *RSA* should be further amended to promote the promotion of an effective safety culture.

# ***Appendices***

Appendix A – References

Appendix B – Crossing Occurrence Data

Appendix C – The Safety Spectrum

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## Appendix B - Crossing Accident Data

### Crossing Accidents by Year (for 2007, data is as of July 10)

2000	2001	2002	2003	2004	2005	2006	2007	Total
264	280	263	251	236	269	248	106	<b>1917</b>

### Crossing Accidents by Impact Type from 2000 to present

	2000		2001		2002		2003		2004		2005		2006		2007	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
MISSING	1	0	2	1	1	0	1	0	.	.	.	.	6	2	52	49
STRUCK BY VEHICLE	85	32	75	27	68	26	70	28	74	31	85	32	69	28	20	19
STRUCK VEHICLE	165	63	193	69	177	67	168	67	154	65	168	62	161	65	30	28
STRUCK PEDESTRIAN	13	5	10	4	17	6	12	5	8	3	16	6	12	5	4	4
Total	264	100	280	100	263	100	251	100	236	100	269	100	248	100	106	100

### Crossing Accidents by Vehicle/Train Flow Volume 2000 to present

NO_XING_TRAINS_DAILY	NO_XING_VEHICLE_DAILY										
	MISSING		0-100		101-1000		1001-10000		10001+		Total
	N	%	N	%	N	%	N	%	N	%	N
MISSING	330	86	.	.	3	1	1	0	.	.	334
0-5	23	6	173	39	125	31	157	28	34	26	512
6-10	14	4	70	16	78	20	145	26	45	35	352
11-25	5	1	113	26	133	33	150	27	25	19	426
26+	13	3	83	19	60	15	112	20	25	19	293
Total	385	100	439	100	399	100	565	100	129	100	1917

**Crossing Accidents by Crossing Location 2000 to Present**

	2000		2001		2002		2003		2004		2005		2006		2007	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
MISSING	5	2	2	1	1	0	1	0	.	.	.	.	10	4	56	53
URBAN	153	58	164	59	161	61	145	58	133	56	160	59	124	50	20	19
RURAL	67	25	67	24	58	22	84	33	69	29	60	22	74	30	25	24
PRIVATE	9	3	10	4	.	.	.	.	.	.	.	.	.	.	.	.
INDUSTRIAL	30	11	37	13	43	16	21	8	34	14	49	18	40	16	5	5
Total	264	100	280	100	263	100	251	100	236	100	269	100	248	100	106	100

**Crossing Accident Vehicle Occupant Fatalities by Approximate Train Speed and Posted Road Speed 2000 to present**

Road Speed	Train Speed										
	Missing	0	1-9	10-19	20-29	30-39	40-49	50-59	60-69	Over 69	
Missing	3	.	0	1	0	2	5	3	2	0	
30 and under	1	.	1	0	3	1	3	2	1	5	
40	.	.	.	.	0	0	0	2	.	0	
45	.	0	.	.	.	.	.	.	.	.	
50	0	0	4	4	9	8	17	13	5	3	
55	.	.	.	.	.	.	0	0	.	.	
60	0	.	0	0	2	5	2	7	7	2	
65	.	.	.	.	.	0	.	.	1	.	
70	.	.	0	0	0	.	2	0	.	3	
80	0	0	3	0	6	6	11	15	5	2	
Over 80	1	.	2	1	3	0	3	3	0	1	
Total	5	0	10	6	23	22	43	45	21	16	

**Crossing Accidents by Crossing Type 2000 to Present**

	2000		2001		2002		2003		2004		2005		2006		2007	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
MISSING	1	0	2	1	1	0	1	0	.	.	.	.	6	2	43	41
PUBLIC AUTOMATED	139	53	145	52	129	49	136	54	117	50	160	59	116	47	32	30
PUBLIC PASSIVE	84	32	77	28	95	36	72	29	64	27	71	26	77	31	24	23
PRIVATE	37	14	48	17	33	13	36	14	51	22	33	12	47	19	7	7
FARM	3	1	8	3	5	2	6	2	4	2	5	2	2	1	.	.
Total	264	100	280	100	263	100	251	100	236	100	269	100	248	100	106	100

## Appendix C – The Safety Spectrum

	Category 1	Category 2	Category 3	Category 4	Category 5
<b>View</b>	Compliance as Cost	Safety as Compliance	Safety as Risk	Safety as Opportunity	Safety as a fully integrated business practice
<b>Issue</b>	Reducing costs	Sanctions (fines, jail, suspensions, etc.)	Waste	Customer/ stakeholder interests	Sustainability
<b>Driver</b>	Minimize compliance expenditures	Minimize sanctions	Minimize costs	Maximize revenues	Maximize profits
<b>Process</b>	Comply when forced to and attribute blame	Internal inspections and audits supported by an internal system of rewards and punishments	Integrate safety programs	Include safety issues in marketing and operational decisions	Fully integrate safety options and issues into all aspects of business
<b>Approach to safety management</b>	Devoid of any approach to safety management	Compliance strategies	Safety Management Systems (SMS)	Safety Management Systems (SMS) + Business Strategies	Safety Management Systems (SMS) + Business Strategies + Business Modeling
<b>Cultural label</b>	Pathological	Reactive	Calculative	Proactive	Generative