CHAPTER 10

GUIDELINES FOR ACCIMAP ANALYSIS

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Introduction

This chapter focuses on a systems-based technique for accident analysis, referred to as the AcciMap approach.[1] The technique involves the construction of a multilayered diagram in which the various causes of an accident are arranged according to their causal remoteness from the outcome. It is particularly useful for establishing how factors in all parts of a sociotechnical system contributed to an organisational accident,[2] and for arranging the causes into a coherent diagram that reveals how they interacted to produce that outcome. By identifying these causal factors and the interrelationships between them in this way, it is possible to identify problem areas that should be addressed to improve the safety of the system and prevent similar occurrences in the future.

AcciMaps have been used to analyse accidents involving the contamination of drinking water (Vicente & Christoffersen 2006; Woo & Vicente 2003), the Toronto severe acute respiratory syndrome outbreak (Piché & Vicente 2005), the Esso Longford gas plant explosion (Hopkins 2000a), the Glenbrook train crash (Hopkins 2005), and several Australian Defence Force aircraft accidents (Naikar, Saunders & Hopkins 2002; RAAF 2001), among others. However, a lack of consistency in how the technique has been applied and the absence of documentation regarding how to conduct such analyses have prevented the approach from being readily accessible to new users. The aim of this chapter is to present a standardised AcciMap format (based on elements of the existing AcciMap varieties) and guidelines for applying the technique. The first part of this chapter discusses the development of the standardised AcciMap approach. The second part presents guidelines for conducting AcciMap analyses.

1 Pronounced *axi-map*, for the *map* of an *accident*.

2 *Organisational* accidents (the type of event that AcciMaps are designed to analyse) are those accidents that take place in complex sociotechnical systems (such as nuclear power stations, chemical process facilities, and aviation, marine and rail transport systems), have "multiple causes involving many people operating at different levels of their respective companies", and can result in damage to people, assets or the environment (Reason 1997, p 1).

Part A: Standardising the AcciMap approach

The AcciMap approach

The AcciMap was developed by Rasmussen (1997) as part of a process for generating proactive risk management strategies for complex sociotechnical systems. Rasmussen views organisational accidents as the result of the loss of control over potentially harmful physical processes, and therefore sees safety as requiring "control of work processes so as to avoid accidental side effects causing harm to people, environment, or investment" (1997, p 184). The AcciMap was developed as a means of analysing the series of events and decision-making processes that interacted to result in this loss of control. For Rasmussen, the AcciMap was one part of a broader process for generalising from a series of accidents to define the conditions for safe operation in a particular type of system, so that risk management strategies could be devised (Rasmussen & Svedung 2000).

However, the AcciMap approach has also been used independently of this broader process to analyse the causes of single accidents. Woo and Vicente (2003), for instance, have used the approach to analyse separate accidents in an effort to determine the types of risk factor that might be common to different systems. Other analysts (Hopkins 2000a, 2005; Naikar, Saunders & Hopkins 2002; RAAF 2001) have used it solely to analyse accidents and assist in safety recommendation development.

The AcciMap approach involves the construction of a causal diagram depicting the events and conditions that interacted to result in an accident. The AcciMap itself is a tree-shaped diagram, with the accident located near the bottom and the causes of that event branching upward (with the more immediate causes in the lower sections of the diagram and the more remote causes towards the top). The causal factors are arranged into a series of levels representing the different parts of the sociotechnical system in which the event took place. The lower levels show the immediate precursors to the accident, while the higher levels incorporate organisational, governmental, regulatory and, in some cases, societal factors that played a role in the occurrence. Each of the causal factors in the diagram is linked to its effects in a way that illustrates how that factor influenced other factors and contributed to the outcome. An AcciMap is therefore a graphical representation of the events and conditions that came together to produce an organisational accident.

There are a number of advantages to this approach. First, it enables analysts to compile large amounts of information — regarding the numerous causes of an organisational accident, the area of the sociotechnical system in which each factor arose, and precisely how the factors came together to produce the accident — within a single, coherent diagram. Such an approach is useful, not only for conveying this information to others in a succinct and logical form, but also for assisting the analyst in building and maintaining an understanding of the complex combination of factors that resulted in the outcome.

Second, the approach promotes a systemic view of accident causation. The AcciMap diagram extends well beyond the immediate causes of an accident to uncover the range of factors throughout the system that promoted the conditions in which an accident occurred, or which failed to prevent the negative outcome. The diagram identifies the factors that led directly to the accident and then progressively identifies the causes of each of these factors, so that the decisions, events and conditions that created the circumstances in which the accident took place are identified. The diagram therefore provides the necessary context for gaining a comprehensive understanding of how and why an accident happened. It also prevents excessive attention from being directed towards the immediate causes of accidents (such as human errors) because the diagram shows that these are the result of higher-level factors, rather than the sole causes. The approach therefore promotes Reason's (1997, 2000) *systems approach* to accident analysis, which is recommended by major accident investigation bodies. The systems approach acknowledges the influences and constraints on the behaviour of individuals working in a system and aims not to blame them for honest errors, but to uncover the systemic deficiencies that provoked those errors and/or failed to prevent them from resulting in an accident. Such an approach focuses on repairing systemic deficiencies to prevent future accidents, rather than reprimanding the individuals involved and leaving the deficiencies that promoted their actions unaddressed.

A third major advantage of the AcciMap approach is that it assists in safety recommendation development. The way the causal factors and their flow-on effects are illustrated in an AcciMap means that analysts can work systematically through the diagram to pinpoint the factors that, if corrected, could prevent a range of potentially hazardous situations from arising. The grouping of the factors into the levels of the sociotechnical system assists in this respect by separating the factors for which corrective actions are useful (namely, those at the organisational level and above) from the *consequences* of those factors (which should not be addressed directly in accordance with a systems approach to accident analysis). The capacity of AcciMaps to incorporate contributing factors beyond the organisational level (for example, factors relating to legislation, regulations, certification, auditing, and government decisions) is also beneficial because identifying these high-level causes enables equally high-level safety recommendations to be devised. This is a "particularly desirable feature" of AcciMaps "because the higher the level of the corrective action, the broader is the class of unwanted events which may be prevented" (Hopkins 2003, p 2). A safety recommendation directed towards a regulatory inadequacy, for instance, can help to improve safety in all organisations under the influence of that regulator, rather than just the single company affected by the accident in question. In addition, since high-level system problems generally have far-reaching negative effects, with the potential to contribute to a number of different types of accident (Reason 1997), addressing these problems can help to prevent a variety of negative outcomes, rather than just a recurrence of the same event.

A major disadvantage of the AcciMap approach, however, is its inaccessibility to new users. In the published examples of AcciMap analyses, the format, underlying logic, scope of analysis, and process taken have all varied, depending on the particular purpose and nature of the analysis. For this reason, a standard format and process for other analysts to follow has not been available. The purpose of this chapter is to present such a format, along with detailed guidelines for use.

The standardised AcciMap

The standardised AcciMap presented in this chapter was not developed by formalising any one of the existing varieties but, rather, by selecting and incorporating the factors common to these varieties and the factors judged most suitable for retrospective accident analysis purposes. The aim in bringing together the existing varieties in this way was to create a standardised approach that incorporates a strict causal logic for identifying causal factors and illustrates how they contributed to the outcome. In addition, the standardised AcciMap is intended to promote the development of safety recommendations and is not specific to a particular domain, so it can be used to analyse organisational accidents in any sociotechnical system. The standardised AcciMap format chosen for these purposes is shown in Figure 1, and the features of the format are described below.

The outcomes

The accident itself, that is, the final negative outcome to be analysed, is located in the lowest section of the diagram with the causes branching upward (as in AcciMaps by Hopkins). In some existing AcciMaps (Rasmussen 1997; Woo & Vicente 2003), the lowest level incorporates factors relating to equipment and physical surroundings, while the immediate accident sequence is located in the second-lowest level, ordered from left to right in temporal order. The placement of the outcome at the bottom of the diagram, in the standardised approach, enables all causes to be arranged strictly in terms of their causal remoteness from the outcome, rather than having causes located both above and below it. This means that all causal links in the diagram face downwards, making the causal chains easy to follow and giving the diagram a logical "tree" structure. Contrary to some versions, there is no suggestion here of a time line moving from left to right. The temporal order must be ascertained from the causal connections, as discussed below.

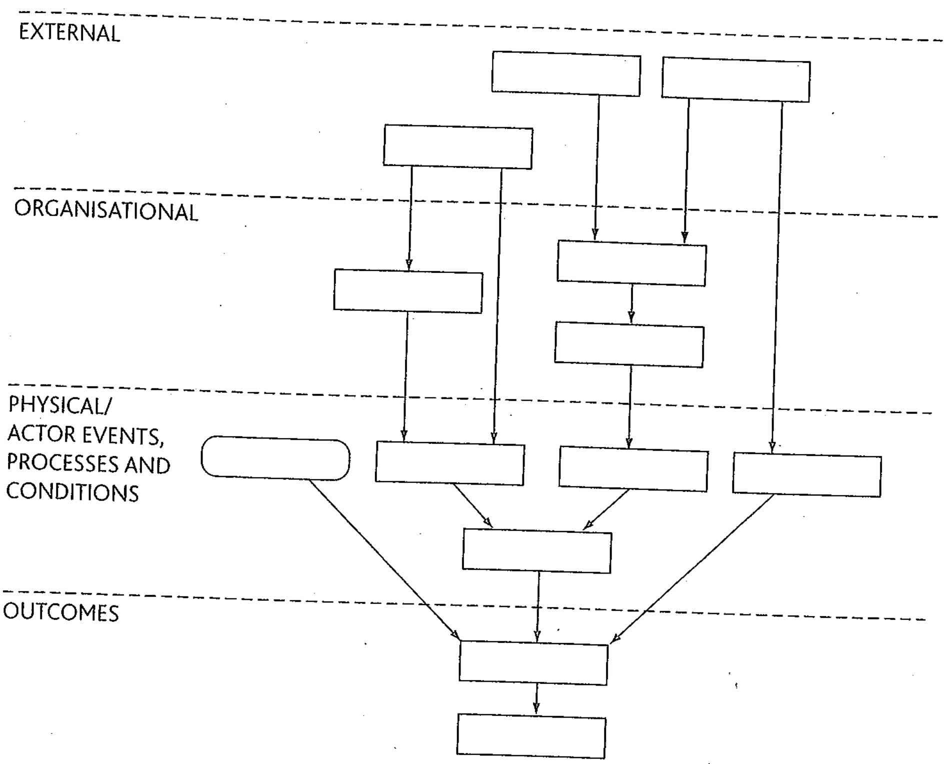


FIGURE 1: The standardised AcciMap format

AcciMap levels

The levels in the existing varieties of AcciMap vary, not only by the overall format adopted, but also by the system in which the accident occurred. However, all are generally modelled on the interacting levels in a complex sociotechnical system, ranging from government and regulatory levels down to the organisational and workplace levels (Rasmussen 1997). The criteria used to select the levels during the standardisation of the approach were that they should be unambiguous, that they should be non-domain-specific, and that they should preserve the causal remoteness in the diagram.

The "Outcomes" heading is adopted from one of Hopkins' AcciMaps (RAAF 2001). On occasions where one negative outcome leads to another (for example, a plane crash and a post-crash fire), more than one outcome can be located in this level.

The "Physical/actor events, processes and conditions" level combines the two lowest levels ("Physical processes and actor activities" and "Equipment and surroundings") of AcciMaps by Rasmussen (1997) and others (Vicente & Christoffersen 2006).

These levels have been combined to incorporate the immediate precursors to the accident relating to both physical factors and the activities of frontline individuals. This heading was designed to provide more guidance on the type of factor that should be located within the level than Hopkins' equivalent term, "Immediate causes" (RAAF 2001).

The "Organisational" level heading is borrowed from Hopkins (2000a) and was chosen because it is a self-explanatory and generic term that can incorporate causes relating to any organisation(s) involved in an accident, regardless of the particular domain. The equivalent terms, "Technical and operational management" (Rasmussen & Svedung 2000) and "Company planning" (Rasmussen 1997) are less generic, so were judged to be less useful for present purposes.

Governmental and regulatory causes are not separated into distinct levels in the standardised AcciMap because governmental causes are sometimes less, and sometimes more, causally remote than regulatory causes, leading to confusion in a diagram arranged by causal remoteness. Rasmussen (1997) has avoided this problem by including three separate levels in some AcciMaps ("Government", "Regulatory bodies" and "Local area government"), so that different types of governmental cause can be placed above or below regulatory factors as required. However, it is simpler, and results in no loss of meaning, to merge these levels, as Hopkins has done with his "Government/regulatory system" level (2000a). These factors are combined into an "External" level in the standardised AcciMap, representing *all* factors beyond the control of the relevant organisation(s). This level includes all causes relating to the government and regulatory bodies and can also incorporate societal-level causes, as Hopkins has included in his AcciMaps (2000a).

Causal factors

The causes in the standardised AcciMap are factors that were *necessary* for the accident to occur, as in Hopkins' AcciMaps. This is because the diagram is designed to identify all of the factors that caused (or failed to prevent) a particular accident, so that an understanding can be gained of how it occurred and where corrective action could be taken to prevent similar occurrences in the future. However, to set useful boundaries on the causes identified, such causes are only included if they are of "practical significance" (that is, if something could conceivably be done about them) (Hopkins 2000a, p 22) or if they are *necessary for making sense of how and why the accident occurred* (that is, if the sequence of events does not make sense without them). The latter are included solely to ensure that the AcciMap contains sufficient information for readers to understand how the accident occurred. These factors are easily distinguished from the others because they are drawn in rectangles with curved edges (the symbol used by Svedung and Rasmussen (2002, p 407) to signify preconditions that are "evaluated no further").

To preserve the simplicity of the diagram, other symbols from the existing varieties of AcciMap are omitted in the standardised AcciMap. These include Rasmussen and Svedung's (2000, p 21) "Decision/action" boxes which show the decision and the "accidental side effect" of that decision in adjacent rectangles, and decision switches, phrased as "yes" or "no" questions (Woo & Vicente 2003). In the standardised approach, decisions which affected the outcome are displayed as rectangles, along with the other events and conditions that were necessary for the outcome. "AND gates", representing instances in which multiple factors were required in order for a consequence to occur, are also excluded from the standardised AcciMap. The same concept is represented simply by allowing several arrows to converge on a single outcome box.

The AcciMap guidelines (presented in Part B of this chapter) specify the process by which analysts can "extract" the necessary causes from the accident data.[3] The process involves the analyst identifying all factors for which he/she can say "had this been otherwise, the accident would probably not have occurred". The analyst is later required to ask *why* each factor took place, in order to identify all of the factors that caused or failed to prevent it. This process of asking "why?" is a common procedure for uncovering additional information in accident analyses and is used by Naikar, Saunders and Hopkins (2002), among others, to identify the systemic causes of accidents. A table providing examples of causes at each AcciMap level is provided in the guidelines to assist analysts in selecting the appropriate level for the causes uncovered. The guidelines suggest that analysts refer to this table during the analysis to check that they have not overlooked any relevant causes. The guidelines also encourage analysts to phrase these factors in a way that focuses the analysis on the systemic contributors, rather than the particular individuals involved.

Causal connections

For Rasmussen and Svedung, AcciMaps are not intended to be a "truthful representation of facts" but rather to identify "factors sensitive to improvement", that is, all of the decision-makers whose decisions could have influenced the events in the lower levels of the diagram. The arrows in their diagrams therefore refer to "influences", but do not necessarily imply causality (2000, pp 20-21). When using the AcciMap approach for the purpose of identifying the causes of accidents, as the standardised AcciMap approach is designed to do, it is useful to adopt more stringent criteria. The arrows in the standardised AcciMap therefore imply strict causation, in the way used by Hopkins (2000a) and Woo and Vicente (2003) in their AcciMaps. A factor is only linked to another if the first was necessary in order for the second to occur. The sequences of causal factors and arrows (or "causal

3 Note that the AcciMap guidelines are designed for analysing accidents using the data collected during the accident investigation, rather than during the initial data-gathering phase.

connections") in an AcciMap therefore illustrate the causes and effects that led the outcome. In order to promote logical and coherent AcciMaps, the guidelin suggest that one cause should only be linked to another if the second was a *dir* cause of the first, that is, that no other factor needs to be inserted between them order for a reader to understand how the first cause led to the second. The differe ways in which causes can be arranged in the diagram are also specified in ord to avoid repetition of causal factors and to ensure that broad problem areas a depicted appropriately.

Safety recommendations

The guidelines provide instructions on how to devise a list of safety recommendatio from an AcciMap. Most AcciMap analysts have not extended their analyses safety recommendation development. However, Hopkins (RAAF 2001) a Naikar, Saunders and Hopkins (2002) have continued their analyses to inclu safety recommendations since, if analyses identify the causes and do not go on identify safety recommendations, the "hard won lessons will be to no avail" (RA 2001, p 1.4).

Safety recommendations are not generated automatically once an AcciMap complete, and it is not the case that every cause identified should be address directly. Rather, safety recommendations "must stem from a consideration of whe it is sensible to seek to make changes" (Naikar, Saunders & Hopkins 2002, p The AcciMap guidelines therefore show how safety recommendation formulatio should be approached but leave the analyst to judge how safety can best be improve The guidelines specify the types of cause for which recommendations should formulated, namely, all of those which could potentially be changed, controlled compensated for to prevent a similar accident from occurring in the future. Th also help the analyst to use the type of wording and level of specificity appropria for a systems approach to accident analysis.

The guidelines for conducting an AcciMap analysis in the way described abo are written in the following stand-alone section, and can be used by analys who are unfamiliar with the AcciMap approach. They therefore begin with background section and a sample AcciMap, followed by step-by-step instructio for performing the analysis. The AcciMap guidelines were developed on the bas of the published descriptions of AcciMap analyses (Hopkins 2000a; Rasmuss & Svedung 2000; Vicente & Christoffersen 2006; Woo & Vicente 2003 supplemented with the authors' experience in performing AcciMap analyse and have been tested and revised in a series of pilot studies. This process w undertaken as part of a project for investigating the reliability and validity AcciMap analyses (Branford 2007). The guidelines have subsequently bee revised for the purposes of this chapter.

Part B: Guidelines for AcciMap analysis

Background to AcciMap analysis[4]

The AcciMap approach is a technique for analysing the causes of accidents. It involves arranging the various causes of an accident into a tree-shaped diagram, with the negative outcome(s) (the accident itself) at the bottom and the causes branching upward. The approach is useful for:

- identifying the broad range of factors that contributed to an accident;
- illustrating how those factors combined to result in the outcome; and
- indicating problem areas that should be addressed to prevent similar events from occurring in the future.

Sample AcciMap

Figure 2 is an example of an AcciMap analysis of a train accident that occurred near Waterfall, NSW, in 2003.[5] Details of the accident are as follows:

> "At approximately 0714 on 31 January 2003, State Rail Authority [SRA] passenger train service C311, a scheduled service from Sydney to Port Kembla, overturned at high speed and collided with stanchions and a rock cutting approximately 2 km south of Waterfall NSW. The train was carrying 47 passengers and two crew. As a result of the accident, the driver and six passengers were killed. The four-car Tangara train, identified as G7, was extensively damaged. The investigation found there was a high probability that the driver became incapacitated at the controls as a result of a pre-existing medical condition, shortly after departing Waterfall Station. The train then continued to accelerate, out of control, with maximum power applied. The deadman system and the guard were the designated risk controls against driver incapacitation. Both controls failed to intervene as intended and C311 overturned on a curve while travelling at approximately 117 km/h … The immediate cause of the accident was the train exceeding the overturning speed for the curve. The systemic causes of the accident were the simultaneous failures of risk controls in the areas of medical standards, deadman system and training." (Ministry of Transport 2003, p 5)

4 This brief introduction is repetitive in the present context but it is included for readers who want to use Part B as a stand-alone document.

5 The AcciMap shown in Figure 2 is for illustrative purposes only and does not incorporate all information relevant to this occurrence. For additional details, see Ministry of Transport (2003). The AcciMap and safety recommendations are derived from information contained in this report.

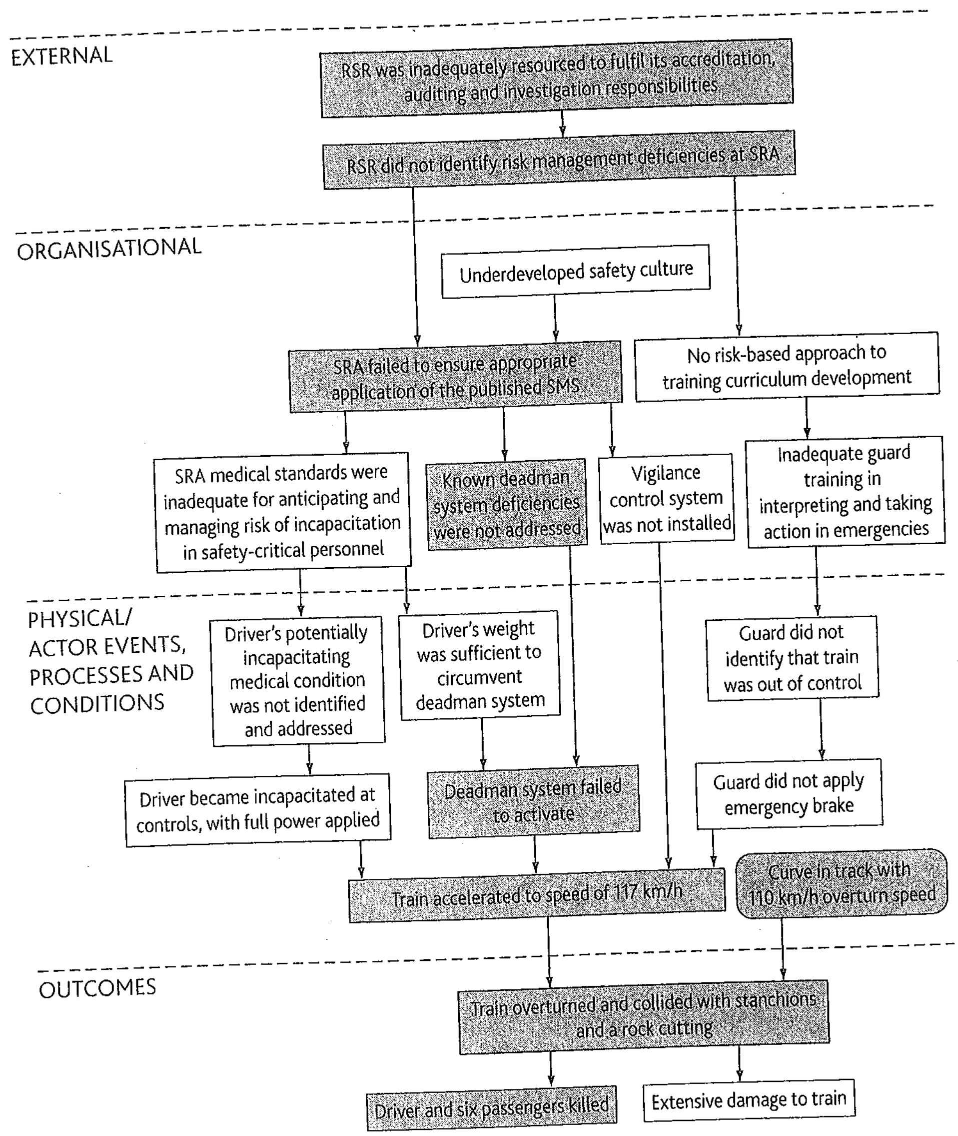


FIGURE 2: Sample AcciMap of Waterfall train accident

The sample AcciMap identifies the accident (in the lowest level of the diagram) and its causes (displayed as boxes and grouped according to their respective levels of causal remoteness). The arrows in the diagram signify causality, with an arrow from one factor to another indicating that the first *caused* the second. By examining the chains of causes in the AcciMap, it is possible to understand the sequence of events and the conditions that produced the accident, and to show that, had any one factor been otherwise, the accident would most likely have been avoided. By following the shaded chain of causes in Figure 2, it is evident that the train overturned and collided with stanchions and a rock cutting (resulting in multiple fatalities) because it accelerated to 117 km/h and exceeded the overturning speed for a curve in the track. One reason why the train accelerated to this speed was that the deadman system, designed to apply emergency breaking in the event of driver incapacitation, failed to activate. The reason for the lack of activation was that a known deficiency with the deadman system, namely, that it was ineffective as a defence against driver incapacitation for drivers weighing more than 110 kg, had not been addressed, and the incapacitated driver in this instance weighed in excess of 110 kg. Following the arrows upwards in the diagram, the reasons why this situation occurred, or was not prevented from occurring, become evident. Had the State Rail Authority (SRA) ensured that the published safety management system (SMS) was applied appropriately, the known risk with the deadman system would probably have been identified, assessed and controlled. The failure to ensure that the published SMS was applied appropriately therefore allowed this deficiency to remain unaddressed. The deficiency in the application of the SMS also remained unaddressed, in part because the rail safety regulator (RSR) did not identify the risk management deficiencies at the SRA and did not, therefore, take action to address them. Continuing to the top of the diagram, it is evident that the RSR did not identify these deficiencies because it did not have sufficient resources to fulfil all of its accreditation, auditing and investigation responsibilities effectively.

By following each of the causal chains up from the accident in this way, it is possible to develop an understanding of how each of the factors came about and how they combined to produce the final outcomes.

It should be noted that there is a potentially infinite number of causes for any event. As Reason (1997) points out, any causal chain could, in theory, be extended back to the big bang. However, for the purposes of accident investigation, only two types of cause are included:

1. causes of *practical significance*. These are causes that something could conceivably be done about (Hopkins 2000a). Note that the sample AcciMap does not show, for instance, that "had the train been scheduled to depart on a different day" or "had the passengers been travelling by bus" the accident would not have occurred. These causes are not of practical significance as no sensible actions can conceivably be taken to address them; and
2. causes that are not of practical significance, but that are necessary for making sense of why the accident occurred. These causes (depicted as ovals) are only included if the AcciMap *does not make sense without them*. The cause "Curve in

track with 110 km/h overturn speed" is included in the sample AcciMap for t reason. There is not much that can conceivably be done about it (since curves rail tracks are not inherently dangerous and cannot always be avoided). Howev it is necessary to include this cause in order for readers to understand why t train overturned. This category of cause includes factors that contributed to t negative outcome(s) but cannot conceivably be changed, either because it wou not be sensible or would not be plausible or possible to do so. Causes relating environmental conditions, physical surroundings, and ongoing social, politi or economic conditions may fit into this category.

Safety recommendations

Once the AcciMap diagram has been completed, with the relevant cau identified at each level, a list of safety recommendations can be compil A list of recommendations from the sample AcciMap is shown in Figure 3. T recommendations are grouped in terms of the party responsible for carrying o the proposed action.

The types of recommendation made depend on the causes in the AcciMap:

- some causes can be *rectified directly*. For instance, the lack of a vigilance cont system as an additional defence against driver incapacitation can be rectifi directly by recommending that the operator considers installing such a syste to its fleet of trains (recommendation 8);
- some causes cannot be rectified directly, but recommendations can be made *prevent their occurrence*. For instance, the cause "Guard did not identify th train was out of control" cannot be dealt with directly, but recommendatio can be made to improve the training provided to crews in interpreting a taking appropriate action in emergency situations so that this situation will less likely to recur (recommendation 9); and
- other causes cannot be prevented (that is, those depicted as ovals), but effo can be made to *compensate for their effects*, where appropriate. For instance, t cause "Curve in track with 110 km/h overturn speed" cannot reasonably prevented. However, the overturn and collision that occurred, in part, as a resu of this factor can be compensated for by strengthening the defences agair excessive train speeds, such as those relating to driver health, deadman system vigilance control systems, and the guard (recommendations 6 to 9).

Note that there are no recommendations specific to the actual individuals involv in the incident. For example, there are no recommendations to punish or dismi the guard for failing to apply the emergency brakes. This is because other guar in the same situation, with the same training and equipment, may easily ha

Government

Recommendation 1: the RSR should be provided with sufficient resources to develop an effective rail safety regulatory regime and to fulfil its auditing and accreditation responsibilities.

Rail Safety Regulator

Recommendation 2: the RSR should review and improve its capacity to identify risk management deficiencies and effectively audit operator safety management systems.

State Rail Authority

Recommendation 3: the SRA should assess and take action to address safety culture deficiencies, particularly with regard to the application of the published safety management system.

Recommendation 4: the SRA should take steps to ensure that the published safety management system is understood and applied appropriately by all employees.

Recommendation 5: the SRA should adopt a risk-based approach to training curriculum development which ensures that hazards to be addressed through training are identified and incorporated into training.

Recommendation 6: the SRA should review and improve the medical standards applied to safety-critical personnel to ensure that risks relating to potentially incapacitating medical conditions are identified and addressed appropriately.

Recommendation 7: the SRA should address the deficiencies with the deadman system, particularly in relation to the risk of inadvertent circumvention for drivers with a body mass in excess of 110 kg.

Recommendation 8: the SRA should consider fitting vigilance control systems to its fleet of trains as an additional defence against driver incapacitation.

Recommendation 9: the SRA should ensure that all crews are trained adequately in interpreting and taking appropriate action in emergency situations.

FIGURE 3: Safety recommendations from sample AcciMap

made the same mistake.[6] Therefore, rather than aiming to change the behaviour of the particular individuals involved, safety recommendations should address the inadequacies that *allowed* this situation to occur at all, so that *any* individual in a similar situation will be prevented from making this type of mistake.

Instructions for AcciMap analysis

AcciMaps can be constructed using a whiteboard or large sheet of paper and sticky notes (as described below) or electronically, depending on the analyst's preference.

6 See Ministry of Transport (2003) for full details of the factors contributing to the guard's behaviour.

Step 1. Create a blank AcciMap format on which to arrange the causes: separate the whiteboard or large sheet of paper into the four sections of the AcciMap, with the headings of the four levels on the left-hand side and horizontal lines separating each level (as in Figure 2).

Step 2. Identify the outcome(s): (1) from the accident data, identify the negative outcome(s) to be analysed; and (2) insert the outcome(s) into the "Outcomes" level of the AcciMap.

Step 3. Identify the causal factors: on a separate page, make a list of all causes in the accident data, that is, all factors for which you can say "had this been otherwise, the accident would (probably) not have occurred". If you are unsure as to whether or not a factor is a cause, include it in the list — it can always be eliminated at a later stage.

Step 4. Identify the appropriate AcciMap level for each cause: next to each cause, write down the name of the AcciMap level in which it belongs. Refer to Table 1 to determine the correct level. The first column in Table 1 defines the levels of an AcciMap and the second provides examples of the types of cause that may be found at each level.

TABLE 1: Level definitions and examples[7]

I. Level definitions	II. Categories of cause		
The **EXTERNAL** level includes causes that are beyond the control of the organisation(s). This level includes factors relating to →	**GOVERNMENT**, for example: • budgeting issues, government cost cutting • inadequate legislation • privatisation, outsourcing • inadequate provision of services	**REGULATORY BODIES**, for example, inadequate: • regulations, communication of regulations • certification, permits • safety standards • enforcement of regulations • auditing	**SOCIETY**, for example: • market forces • societal values, priorities (such as the public's requirement for quality, efficiency, comfort, affordability) • historical events • global politics

7 This list of examples incorporates causal factors identified by Hopkins (2000a), Kletz (1993), Naikar, Saunders & Hopkins (2002), Rasmussen & Svedung (2000), Reason (1997), RAAF (2001), Snook (2000), Vicente & Christoffersen (2006), and Woo & Vicente (2003).

I. Level definitions	II. Categories of cause	
The **ORGANISATIONAL** level incorporates causes relating to organisational processes. Factors are placed in this level if they are within the control of the organisation(s) involved, for example →	**FINANCIAL ISSUES**, for example: • organisational budgeting, cost cutting • resource allocation problems **EQUIPMENT AND DESIGN**, for example: • design problems (such as ergonomic issues, inaccessibility) • equipment problems (such as poor quality, defective, ageing, untidy, missing or poorly-maintained equipment or tools) • equipment not used as designed **DEFENCES**, for example, inadequate, insufficient or missing: • proactive system defences (such as alarms, warnings, barriers, personal protective equipment) • reactive system defences (such as hazard containment, protection, escape and rescue systems) **COMMUNICATION AND INFORMATION**, for example, inadequate: • information or knowledge • flow or organisation of information • communication of instructions, hazards, priorities, objectives, etc **AUDITING AND RULE ENFORCEMENT**, for example, inadequate: • implementation and enforcement of rules, regulations or procedures • internal auditing, inspection	**ORGANISATIONAL CULTURE**, for example: • incompatible goals (between safety and production or safety and budget, etc) • organisational acceptance or encouragement of short cuts, non-compliance, etc **RISK MANAGEMENT**, for example, inadequate: • hazard identification or risk assessment • hazard or defects reporting • processes for learning from past mistakes • awareness of risks • security (such as protection from unauthorised access) **MANUALS AND PROCEDURES**, for example: • inadequate, ambiguous, conflicting, outdated, absent or difficult to follow procedures, rules, regulations or manuals **HUMAN RESOURCES**, for example, inadequate or insufficient: • supervision, management, coordination, staff numbers • delegation, accountability • staff selection procedures or criteria **TRAINING**, for example, inadequate or insufficient: • training, training equipment, training exercises • training needs analysis

... continued

I. Level definitions	II. Categories of cause	
PHYSICAL/ACTOR EVENTS, PROCESSES AND CONDITIONS are the immediate precursors to the outcome(s) and should include factors relating to →	**PHYSICAL EVENTS, PROCESSES AND CONDITIONS**, for example: • physical sequence of events (including technical failures) • environmental conditions and factors relating to physical surroundings which are necessary for making sense of the sequence of events	**ACTOR ACTIVITIES AND CONDITIONS**, for example: • human errors, mistakes, violations, actions, activities, etc • false perceptions, misinterpretations, misunderstandings, loss of situational awareness, etc • physical and mental status of actors (such as fatigue, ill health, inattention, unconsciousness, intoxication)

Step 5. Prepare the causes: write each identified cause on a sticky note (or equivalent) making sure that you:

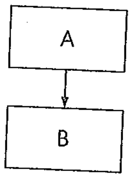
- keep it brief;
- use wording that makes it clear how things might have been different, that is, don't just say "training" or "operator actions", say "inadequate training" or "operator failed to monitor temperature" so that what went wrong is clear; and
- use wording that suits the level that the cause is located in:
  - causes at the "Physical/actor events, processes and conditions" level should be phrased in terms of the actual errors, failures, conditions and events that led to the accident (for example, "life raft failed to inflate" or "pilot failed to adjust heading"); and
  - causes at the "Organisational" level and above should not focus on the particular individuals involved (for example, say "inadequate pilot training" *not* "Pete Smith had not been adequately trained").

Insert each sticky note (cause) into its appropriate level in the AcciMap.

If you have identified any causes which are not of practical significance but which need to be included so that the AcciMap makes sense, draw an oval around these factors to distinguish them from the other causes.

Step 6. Insert the causal links: rearrange the causes in the AcciMap so that the causes lie directly above their effects (whether the effects are in the same level or in the level(s) below).

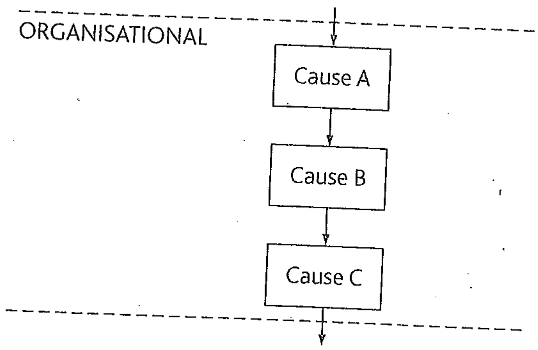
Consider each cause in the diagram and insert a causal link between a cause and its effect if the following criteria are met:



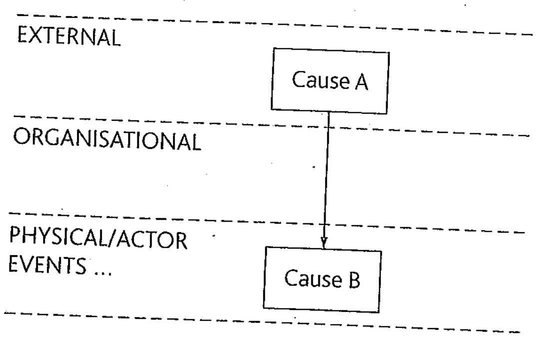
- had A not occurred, B would (probably) not have occurred either; and
- B is a direct result of A; no other factor needs to be inserted between them.

If one cause does not obviously lead on to the next, leave a space where the missing information can be inserted later.

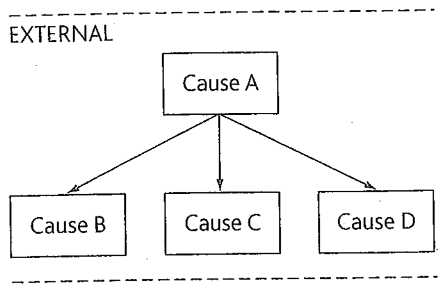
There is no limit to the number of causes to be included in any causal chain, and there may be multiple linked causes within the same level of the AcciMap:

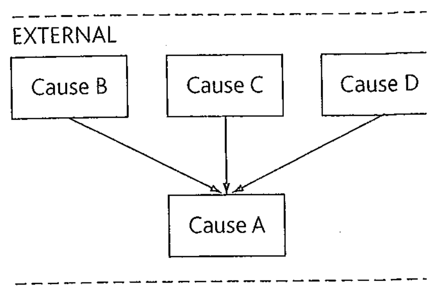


Causes do not have to be linked to effects in the same level or in the level immediately below — they may be linked to factors several levels below:



Some causes may be linked with more than one effect. Conversely, several causes may be linked to one common effect. This means that no cause ever needs to be listed more than once in an AcciMap:





Step 7. Fill in the gaps: at this point, there may be gaps left in the causal chain: where information is missing. These gaps must be filled so that the causal chains ar unbroken from the earliest identified causes in each chain all the way down t the outcome(s), and so that every cause relevant to the accident is included in th AcciMap.

In order to uncover any missing causes, look at each cause on the AcciMap and as why it occurred. Your AcciMap must include all factors which caused its occurrenc or which failed to prevent it from occurring. Refer to Table 1 for help at this poin Table 1 is not an exhaustive list but it will serve as a guide to the types of factor tha may be relevant.

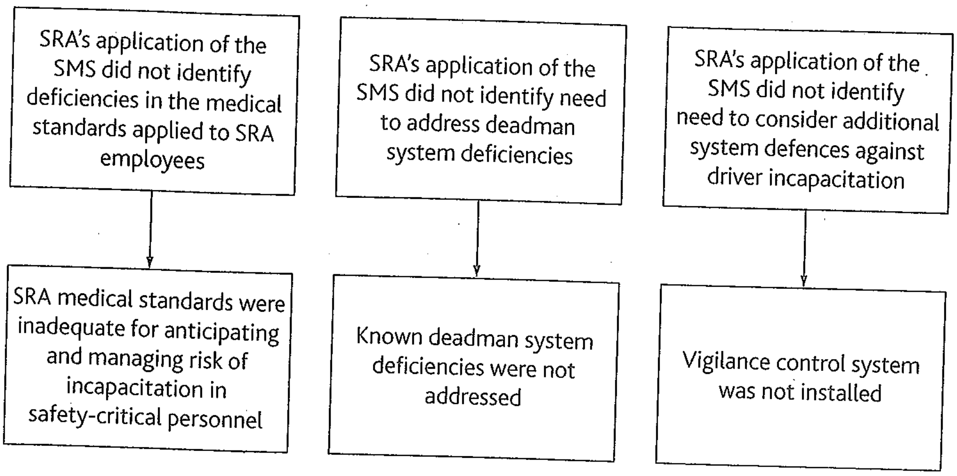
Aim to follow each causal chain as far as possible. Each chain should extend at leas to the "Organisational" level (with the exception of the oval-shaped causes).

Be sure to include as many (but only as many) factors as are necessary so tha someone reading your AcciMap will be able to understand the sequence of even and conditions without difficulty.

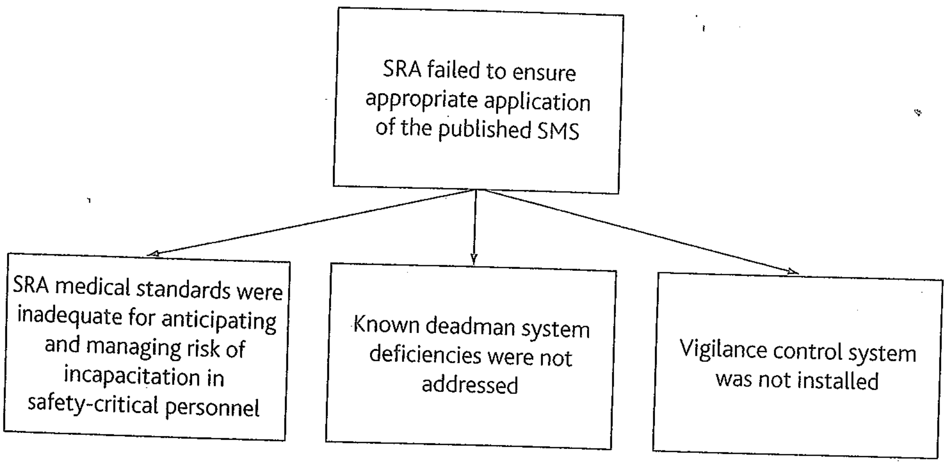
Step 8. Check the causal logic: go through each cause in the diagram and make su that, had it not occurred, the factor(s) it is linked to (and the accident itself) woul probably not have occurred.

Go through each causal chain in the diagram and make sure that:

- anyone reading the AcciMap will have no difficulty in making sense of th sequence of events;
- all of the arrows are facing downwards, towards the outcome(s); and
- no cause is listed more than once. If you have two or more similar causes, see they can sensibly be combined into one more general cause. For instance, th following causes:



can be combined as follows (as they are in the sample AcciMap), to simplify the diagram and to highlight that the SRA's application of the published SMS was inadequate in a number of respects and is therefore a problem area that should be addressed.



Step 9. Formulate safety recommendations: go through each of the causal factors in your AcciMap and identify those which could potentially be *changed*, *controlled* or *compensated for* so that a similar outcome could not occur again.

Bearing in mind that safety recommendations must be practical to implement:

- formulate safety recommendations that identify what *specifically* should be done to change, control or compensate for each cause;
- consider whether or not there is a more *general* problem area that should also be addressed (for example, if there are one or more problems relating to a

certain part of a manual, it may be beneficial to recommend that the manual be reviewed, as well as the particular problem parts, to ensure that any inadequacies are addressed); and

- identify the party responsible for making the required changes.

Note: recommendations should aim to prevent similar accidents from occurring *regardless of the individuals involved or the particular circumstances.*

Compile a list of these recommendations, grouped according to the parties responsible for carrying out the actions (as in Figure 3). Each recommendation should be numbered and should identify the party responsible for making the change.

Finally, check that every cause you identified in the first part of Step 9 has been addressed by one or more recommendation, if appropriate.

Note: not all recommendations will necessarily be accepted by those responsible for implementing them. Issues of practicality, redundancy and cost-effectiveness may be relevant, and alternative solutions may be taken into consideration.

Conclusion

This chapter has aimed to address the inaccessibility of the AcciMap approach to new users by presenting a standardised AcciMap format (developed on the basis of the existing varieties of AcciMap) and a set of guidelines for applying this technique to analyse organisational accidents. The guidelines are intended to assist analysts in developing an AcciMap diagram which will illustrate the multiple systemic causes of an organisational accident and show precisely how they interacted to result in that outcome. The approach is useful for organising and conveying information regarding the events and conditions contributing to an accident, for promoting a systemic view of accident causation, and for assisting analysts to pinpoint problem areas within the system which should be addressed to prevent recurrences.

Acknowledgments

The authors would like to thank the Defence Science and Technology Organisation (DSTO) for granting the first author a PhD scholarship for conducting this research. They also appreciate the time and effort of those DSTO employees who participated in the pilot studies leading to the refinement of the AcciMap analysis guidelines.