A Cascade of Consequences: Improving an Accident Analysis Method by Learning from a Real Life Telecommunications Accident

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Abstract: Telecommunications networks are vital enablers of modern society. Large accidents in these networks that cause their unavailability can therefore have a severe impact on the functioning of society. Learning from these accidents can help prevent them and thus make our society more resilient. In this paper, we present an accident analysis method (TRAM) which we have developed by extending the AcciMap method and we report on its application to analyse a severe accident in a telecommunications network. We validate notation for representing and breaking positive feedback loops in a network breakdown, and we suggest a method to enhance the prioritisation of recommendations derived from our analysis. Furthermore, our research reveals that splitting the analysis based on the expertise of the method's participants negatively impacts the efficiency of the overall process.

1 INTRODUCTION

Telecommunications networks constitute one of the critical infrastructures that make society work. Much attention is therefore paid to the stability and resilience of these networks. When accidents[1] do occur, accident analysis yields insights that can help prevent future accidents and improve the stability and resilience of telecommunications networks.

Our research aims to improve existing accident analysis methods in the telecommunications sector. In our previous case studies, we designed and validated an accident analysis method called TRAM, which enables the modelling and analysis of the distinctive features associated with incidents in telecommunications and cyberattacks (Wienen et al., 2019; Wienen et al., 2024). Our investigation is carried out in real-world corporate settings, characterized by time constraints and limited collaboration opportunities in which these companies operate. This precludes us from conducting controlled experiments. Instead we apply TAR (Technical Action Research) (Wieringa, 2014) to identify new issues during the tests and validation of our accident analysis method. We put our method to the test in an uncontrolled environment, and as the tests progress, the method is adapted to handle unexpected issues encountered during those tests, hence yielding an improved version of the method.

As outlined in our previous case study (Wienen et al., 2024), we concluded that the current version of TRAM lacks the ability to model positive feedback loops, while these types of loops can play a crucial role in telecommunications accidents. We also observed that the number of recommendations for improvement TRAM yielded was large. Prioritising recommendations for implementation is not trivial, yet TRAM originally did not give guidelines on how to make these choices.

TRAM prescribes that subject matter experts should discuss causes and consequences that lead to the accident being analysed. We have seen in previous research (Wienen et al., 2019; Wienen et al., 2024) that splitting the group according to different phases in the accident can increase the efficiency of the method, but we wanted to investigate if splitting the group according to expertise yields a further increase in efficiency. Together with a large telecommunications operator we performed a case study in which we could analyse a large incident in a telecommunications network that led to the large scale unavailability of telecommunications services in a Western European country. In the analysis of this acci-

[1]In the telecommunications domain, accidents are often referred to as 'incidents' . This paper will consistently use the term 'accident' to align with the terminology in the accident analysis field.

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dent, we investigate these three questions (notation for a feedback loop, prioritising recommendations and splitting the group according to expertise).

This article makes the following contributions: (i) it validates the new notation we introduced in (Wienen et al., 2024); (ii) it suggests ways to prioritise the implementation of recommendations resulting from TRAM; and (iii) it discusses the impact of splitting the analysis over two groups of experts according to expertise.

The paper is further structured as follows: Section 2 discusses accident analysis methods; Section 3 describes the TRAM method; Section 4 describes the accident that we used to improve and validate TRAM. Section 5 presents the results of the application of TRAM to this accident and Section 6 discusses these results. Section 7 concludes this paper.

2 ACCIDENT ANALYSIS METHODS

Three different families of accident analysis methods can be identified in the literature (Hollnagel, 2002; Hollnagel and Goteman, 2004; Wienen et al., 2018):

Sequential Methods. Methods that represent an accident as the outcome of a sequence of events.

Epidemiological Methods. Methods that represent an accident as the outcome of a sequence of events that could take place in an environment in which the measures that should have inhibited the sequence to result in an accident were malfunctioning or missing. They take the socio-technical context into consideration, also discussing aspects such as company culture, risk management, budgeting choices and safety regulations.

Systemic Methods. Methods that not only take the socio-technical context into account, but try to model the system in which the accident has developed, thus also looking at the tight links between parts of the system, positive and negative feedback loops and discrepancies between the mental model based on which operators take decisions and the physical reality that they are influencing.

Some methods do not fall into one of the three aforementioned families; these methods are mostly ad hoc and the subject of very limited research (Wienen et al., 2018).

The development of the three families is chronological. The sequential methods were developed first. The Fault Tree Analysis method (Vesely et al., 1981) is an example of such a method. Starting in the 1990s, the relevance of the socio-technical context became apparent, and the first epidemiological methods were developed (Reason, 1990; Rasmussen, 1997). Finally, in the 2000s, system-theoretical aspects were introduced, resulting in the development of systemic methods, such as STAMP (Leveson, 2004) and FRAM (Hollnagel and Goteman, 2004). This evolution was triggered by new accidents that could not satisfactorily be analysed by the existing methods. The relevance of the socio-technical context became evident after, amongst others, the Bhopal disaster, the Challenger explosion and the Chernobyl nuclear disaster (Reason, 1990). The development of the systemic methods started as software took a more prominent role in both the design and the running of systems, thereby creating new vectors for disaster (Leveson, 2004).

In our research, we started with the most cited epidemiological method, namely AcciMap (Rasmussen, 1997; Branford et al., 2009), rather than a systemic method. Systemic methods take more effort as they typically include a data gathering and analysis phase to model the context of the accident (Salmon et al., 2012). This phase is too expensive, since it involves an analysis of the organisation (including training programs and company regulations), government policy and regulations, and regulatory bodies (Salmon et al., 2012) which costs a considerable amount of effort. Systemic methods are therefore not appropriate for most commercial companies.

When we performed our first case study with AcciMap for an accident in telecommunications (a DDOS-attack on a Western European telecommunications provider) (Wienen et al., 2019) we observed that ICT aspects were given too little attention in the AcciMap methods described in literature. These aspects form a critical part of any telecommunications operator and of the technology that also enables malicious actions, such as cyberattacks. We introduced the ICT layer to better analyse these aspects and we also devised several ways to improve the efficiency of the method. These changes gave rise to the Telecommunications related AcciMap (TRAM) method.

3 TRAM

TRAM is an extension of the *Generic AcciMap Method* by Branford (Branford et al., 2009), which is a way to apply AcciMap and to make it practically useful. In its essence, the *Generic AcciMap Method* maps a graph of causes and consequences to a set of layers that represent the organisation in which the accident occurred, the external world, the physical world in

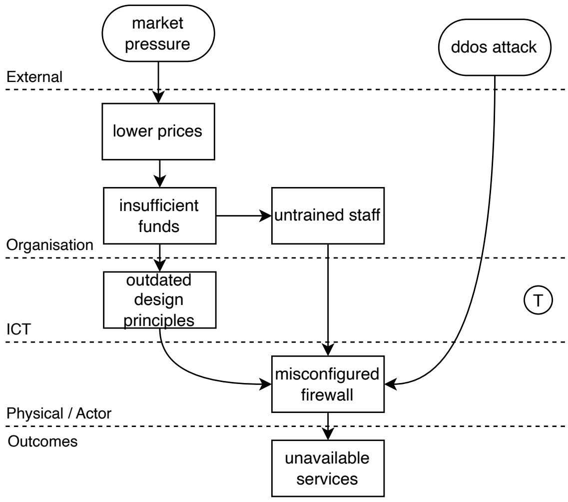

Figure 1: A constructed example of a TRAM diagram.

which actors perform actions and a layer that contains the outcomes.

3.1 Method Overview

Figure 1 shows an example of a TRAM diagram. Our additions to the *Generic AcciMap Method* are indicated by (T) in the figure and in the text that follows.

To apply TRAM, we organise workshops with subject matter experts from the organisation in which the accident occurred. We then analyse the accident according to the following steps:

1. **Prepare the Analysis Workshop.** Study available documentation to prepare the analysis workshops and to draw up a list of participants.
2. (T) **Identify the Physical Path.** Identify the technical failures that caused the accident and draw a diagram representing these technical failures. In this way, a common picture is formed among the participants in neutral terms, helping avoid the 'blame game'.
3. (T) **Split the Accident and the Group.** The accident can sometimes be split into two distinct phases, such as *e.g.* a short-lasting power outage and a subsequent longer service outage, or the onset of the actual accident and the resolution of the crisis situation caused by the accident. If this is the case, split the group so that each phase of the accident is analysed by the staff involved in that phase.
4. **Identify the Outcomes.** Identify the consequences of the accident. These may be detrimental, but also beneficial, such as using the crisis to implement long-delayed improvements.
5. **Identify the Causal Factors.** Identify all causal factors (these are the nodes in the causal chain of events or the boxes in the diagram). In this step, it is pertinent that the group does not limit itself to actual events, but also takes into account measures that were supposed to stop the development of the accident or mitigate consequences, but failed.
6. (T) **Identify the Appropriate Layer.** A TRAM diagram is layered, containing layers for External, Organisational, ICT and Physical/Actor causal factors. Each causal factor is plotted in a layer.
7. (T) **Bring the Groups and the Diagrams Together.** If the group has been split in step 3, the groups are now recombined, review each other's diagrams and combine the diagrams.
8. **Fill Gaps and Check Logic.** In this step, the group walks through the whole causal chain, identifying missing causal factors and faulty links, finalising the diagram.
9. **Formulate Recommendations.** For each causal factor, the group discusses how to *prevent* those factors from happening, how to *control* them if they are happening and how to *compensate* or *mitigate* the consequences once the factor has happened. These recommendations must be formulated in actionable form as they are the harvest of the analysis.

When creating TRAM, we added steps and layers as indicated above. We also defined additional notation to indicate positive feedback loops and heuristics to discuss Crisis Management after the accident occurred. This resulted in a 25% more efficient approach by splitting the group and avoiding discussions about blame, as well as a more effective approach by clearly indicating ICT aspects and by adding Crisis Management to the analysis (Wienen et al., 2024).

3.2 Positive Feedback Loops

TRAM diagrams are cause-and-effect diagrams, so that in essence they are directional non-circular graphs. In (Wienen et al., 2024) a positive feedback loop was instrumental in causing the accident. Adequately representing these loops in a strict cause-and-effect diagram is hard, because it either requires a repetitive string of actions, or the positive feedback loop must be modelled as a single event. However, in the latter case, the parts that make up the loop and the way to break it are not represented. This is why we introduced new notation to represent these loops. We relaxed the non-circularity requirement, enabling us to draw the feedback loop with adequate details to show where the loop could be interrupted. The notation consists of a valve symbol ($\bowtie$) to indicate where the loop was interrupted and which action interrupted the loop. Figure 2 shows an example of this notation. This is the actual feedback loop that appeared in our case study. The numbers in the boxes refer to the numbers in Figure 3. The feedback loop is indicated by the dashed red box; the action to break the feedback loop is indicated by the square with the arrow pointing at the middle of the $\bowtie$ symbol, while the $\bowtie$ symbol itself indicates the link that is cut to break the loop.

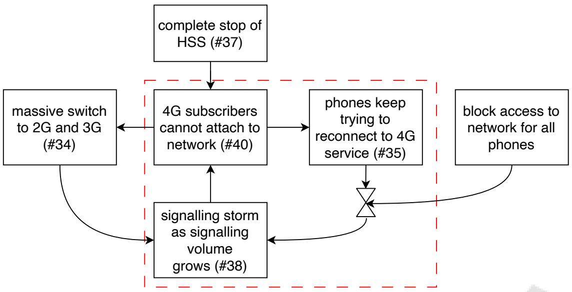

Figure 2: Application of the notation we introduced in (Wienen et al., 2024) to the feedback loop that was instrumental in the accident in this case study.

3.3 Prioritising Recommendations

Previous applications of the method (Wienen et al., 2019; Wienen et al., 2024) yielded many recommendations (136 recommendations in Case Study 1 and 63 recommendations in Case Study 2). Choosing which recommendations to implement and in what order is not trivial. For this reason, we wanted to investigate in the current case study if we could prioritise the recommendations according to two methods: (i) a cost-benefit analysis in which we use a scale from 1 to 5 on both axes and (ii) a maturity model.

Many maturity models are described in the literature (Smit, 2005; Mahal, 2008; Junttila, 2014; Reis et al., 2017; Malone et al., 2020) and some models even describe how to build maturity models, such as (Maier et al., 2012). (Junttila, 2014) identifies six different maturity model development processes, while(Malone et al., 2020) describes 21 different maturity models for 6 different domains, such as Business Intelligence, Human Resources and Software Development / Technology. Maturity models typically have two dimensions (Lacerda and von Wangenheim, 2018): (i) one dimension that describes process areas, capabilities or characteristics of the domain, and (ii) one dimension that describes the maturity the organisation has achieved in one of the process areas or capabilities in the first dimension.

We chose to use discrete levels for the maturity dimension instead of a continuous scale so that the participants in the case study can more easily order the different recommendations. The majority of the maturity models in (Malone et al., 2020) (13 out of 21) and in (Lacerda and von Wangenheim, 2018) (8 out of 11) use 5 levels of maturity, so we also used 5 levels. By giving descriptions to the different levels, the participants have heuristics to assign recommendations to a level.

We took the description of the levels from a study by (Lacerda and von Wangenheim, 2018). In this study, the authors identify eleven models, of which four use the same scales, while the other seven use scales that are all distinct. Three models in (Malone et al., 2020) use the same scales as the four in (Lacerda and von Wangenheim, 2018). These are all maturity models in the Software Development / Technology domain. All other maturity models in (Malone et al., 2020) use distinct names for the levels. The common scales are shown in Table 1; we adapted the descriptions to make them more generic.

Table 1: Common scale in Maturity Models, adapted from (Lacerda and von Wangenheim, 2018).

Stage	Description
1 – Initial	No processes exist; work is done according to the individual's own preferences and approaches differ between applications
2 – Repeatable	Work is done according to a repeatable approach which exists in the employee's mind
3 – Defined	Work is done according to a documented procedure
4 – Managed	Work is done according to a documented procedure and the procedure is evaluated and adapted on a frequent basis to improve efficiency and adaptability to changes in the environment of the work
5 – Optimising	Data is gathered and used to improve the efficiency and effectiveness of the procedures

To reduce the complexity of prioritising the recommendations even further, we decided to cluster the recommendations and only prioritise the recommendations inside a cluster. To this end, we planned to let the researchers and the staff from the telecommunications operator cluster recommendations according to their business function. We named the resulting clusters according to the business function and we named these functions *capabilities*, Our intention was for the subject matter experts to prioritise the different recommendations, taking into account that some recommendations require that other recommendations are implemented first. The subject matter experts would then map all recommendations on the maturity scale in Table 1, and that would define the priority of each recommendation.

3.4 Review of the Diagrams

Drawing up the diagram is a lot of work: in our previous case studies (Wienen et al., 2019; Wienen et al., 2024), it took 2 or 3 workshops to complete all 9 steps. We observed that efficiency is improved by documenting the diagrams using a drawing tool (`draw.io`) and sending digital copies out for review between the different workshops. This enhancement improves quality by introducing an additional online review round, while also boosting efficiency by allowing remarks to be processed offline. This, in turn, avoids consuming valuable time from the subject matter experts.

4 ACCIDENT

Due to the sensitive nature of the accident, we use the pseudonym *Gamma* for the name of the company. Furthermore, some details have been left out as they may reveal their identity. This is also the reason why we use numbers instead of descriptive text in the boxes in Figure 3.

4.1 Cause: Congestion

Sometime in 2018, Gamma virtualised a key component of their network (an STP, or *Signal Transfer Point* which is a routing device used to set up phone calls). This device had been operational for a while until Gamma needed to roll out a change in the device's configuration. In preparation for this change, Gamma created a snapshot (a backup) of the virtual STP, so that a rollback could be executed in case anything went wrong after the change.

During the creation of this snapshot, the virtual STP became unresponsive for a few seconds. During this time, another network element (the HSS, or *Home Subscriber Server*, which is the database that contains information about subscribers and the services they use) sent traffic to the STP that the STP could not acknowledge. This caused a buffer overrun in the HSS, resulting in a complete stop of the HSS. Due to this stop, subscribers could no longer access the network's 4G service. Their devices then switched to 2G and 3G all at the same time, while simultaneously trying to reach the 4G service, resulting in a signalling storm that subsequently overloaded the HSS and caused a complete loss of service.

Gamma resolved the issue by blocking access to the network for all phones and then restarting the HSS. By controlled release of the phones in small batches, service could be restored. Figure 3 shows the TRAM diagram of the accident. It includes the positive feedback loop (# 40 – # 35 – # 38 – # 40) that caused the congestion which resulted in the network breakdown (# 41). The triangles with *A* and *B* are connections to the diagrams that represent the consequences. These diagrams are not included in this paper.

4.2 Consequence: Crisis

Gamma was not prepared for this crisis, since for budgetary reasons they had no centralised crisis communication organisation and no adequate tooling. Furthermore, the Gamma staff only had Gamma subscriptions for their phone, basically rendering the whole organisation unable to communicate internally during the first period of the crisis. The only available channel for communication was a WhatsApp group, severely hindering adequate communication during the crisis.

Since company Gamma is the telecommunications service provider for the government and for the hospitals of their country, communications within the government broke down, and hospitals could no longer be reached. The Ministry of Economic Affairs, which was aware of the crisis before the company's liaison was, held them to account. This led to further reputation damage.

5 RESULTS OF THE ACCIDENT ANALYSIS

We analysed the accident with TRAM in four workshops, namely two with technical staff and two with communications staff, uncovering 91 causal factors, leading to 65 outcomes. In the workshops, 265 recommendations the company could implement were identified.

5.1 Feedback Loop

As shown in Figure 3, a feedback loop was instrumental in the breakdown of the network. Breaking that loop enabled the company to restore service. Using the notation we introduced in the previous case study

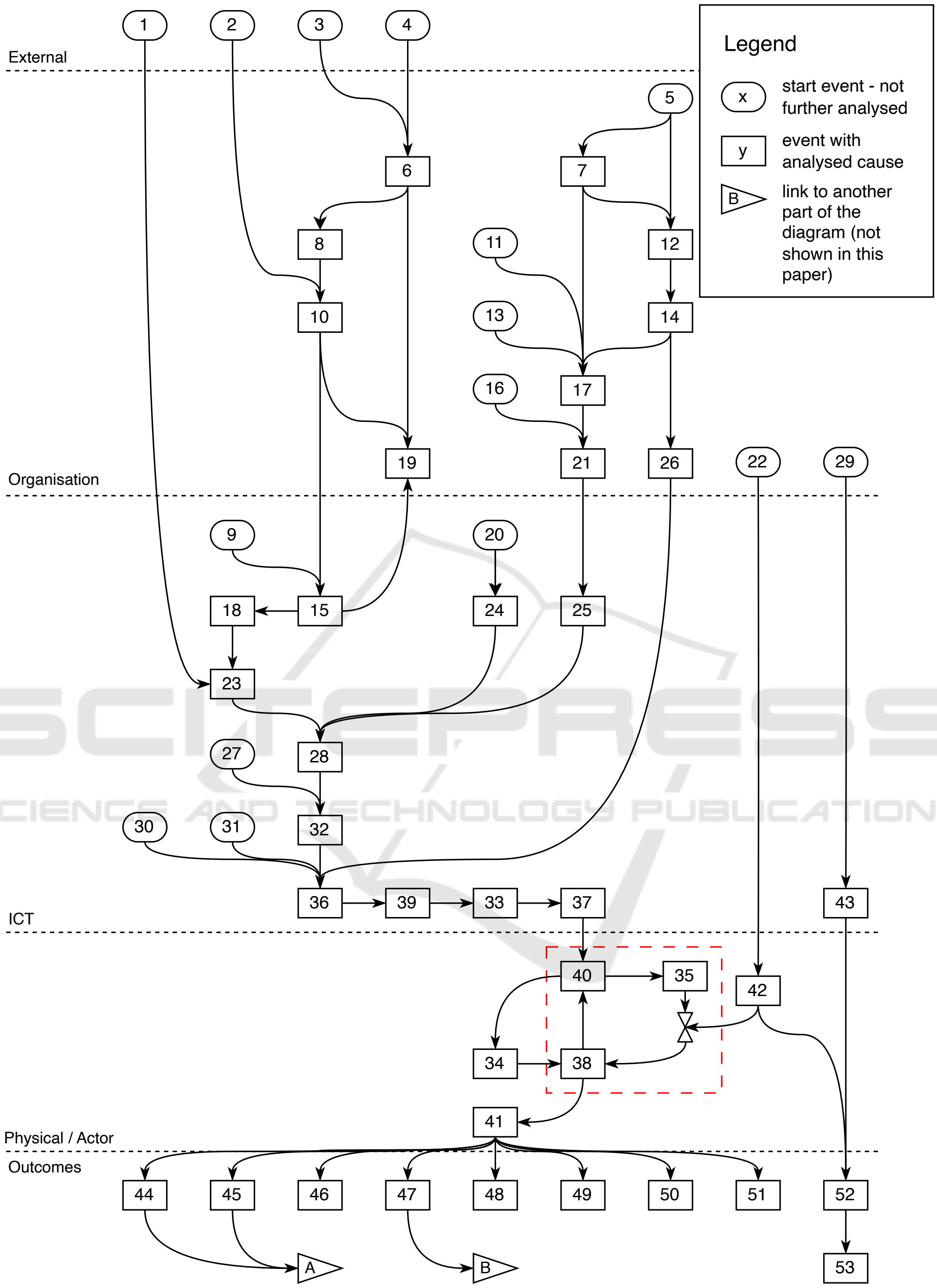

Figure 3: TRAM diagram of the technical part of the accident.

(Wienen et al., 2024), we were able to model both the feedback loop itself and the interruption of the feedback loop. The level of detail yielded recommendations for both the prevention and the interruption of the feedback loop, thus validating and justifying the notation.

5.2 Prioritisation by Maturity Level

After formulating the recommendations with the participants of the workshops, we had a follow-up workshop with the company's business continuity managers. In this workshop, we clustered the recommendations, as shown in Table 2.

Table 2: Clusters of recommendations.

Cluster description	# recommendations
Manage Communications	107
Manage Crisis	81
Manage Growth and Maturity	16
Manage Problem	10
Manage Reporting	1
Manage Resilience	44
Manage Resolution of Situation	6

We then asked the business continuity managers to share the clustered recommendations with the participants in the workshops and ask them to order the recommendations according to dependence (which recommendations could be implemented right away, and which were dependent on other recommendations that needed to be implemented first) and according to urgency (which recommendations needed to be implemented as soon as possible and which could wait). This information, together with the recommendation itself, would enable us to plot them on the scale shown in Table 1.

Unfortunately, the business continuity managers were not able to incite the participants into completing this task, which prevented us from achieving these specific results. For the same reason, we were not able to formulate costs and benefits either. This illustrates one of the difficulties frequently encountered when applying TAR.

A way to circumvent this unresponsiveness of the participants after the workshops are done is to ensure that the analysis has a sponsor at senior management level. The results are aimed at improving the resilience of the company, thereby helping assure business continuity. This is a responsibility of the board and therefore senior management sponsorship can be justified. Senior management can compel employees to cooperate, while the business continuity managers can only ask.

5.3 Splitting the Group According to Expertise

The workshops started during the COVID-19 pandemic, when gatherings were prohibited, so we performed our workshops online, using Microsoft Teams and Excel to run the workshop. This had an impact on efficiency, and the way the workshops were run was not comparable to the previous workshops we conducted, in which people gathered in a room around a brown paper wall. This makes it impossible to draw conclusions about efficiency with respect to splitting the groups according to expertise.

We did notice, however, that in the workshops we had a harder time making certain that 'the other side' (operations versus communications) was not blamed. We did not observe the sharing of ideas between different areas of expertise in the workshops, unlike what we saw in our previous case studies. In the workshops of those case studies, the interaction led to a common goal of learning from the accident on a broader scale than just within individual departments.

6 DISCUSSION

In this section, we discuss the main lessons of our case study.

Feedback Loop. Adding the notation for feedback loops has two benefits:

1. It allows to represent one of the material causes of the accident, giving more insight in the development of the accident and possible ways to prevent such a feedback loop from occurring at all.
2. It shows how the positive feedback loop can be broken. Breaking the feedback loop gives valuable recommendations for future accidents in which this feedback loop plays a role. Identifying its solution enables the organisation to draw up step-by-step instructions for managing this type of situation.

Prioritisation. We were not able to prioritise the recommendations with company Gamma, as we never received their feedback. We propose to involve senior management to instruct staff to cooperate with the analysis.

By identifying clusters of recommendation, we were however able to formulate candidates for capabilities that could be part of a maturity model. This preliminary result needs to be validated in other case studies.

Splitting the Group According to Expertise. Although we were not able to make a quantitative comparison of the efficiency of the meetings, we did observe that splitting the group along lines of expertise removed a valuable aspect of the previous case studies: the sense of a common goal between different departments and achieving an atmosphere in which the principle of 'no blame' could be applied more easily. However, due to the different circumstances in which we conducted this case study as compared with our previous study (Wienen et al., 2024), we cannot draw general conclusions from this observation.

Threats to Validity. A threat to the validity of our results is that these are the results of a single case study (in the case of the notation for the positive feedback 2 case studies). The capabilities for telecommunications business continuity are drawn from the recommendations, which, in turn, are a result of the actual accident. Other accidents may yield different capabilities.

Another threat to the validity is that the workshops were conducted online due to COVID lock downs. It is not possible to distinguish between the impact of online working and the effect of splitting up the group according to expertise.

7 FINAL REMARKS

In this paper, we discussed the application and enhancements of TRAM, which is a method for analysing accidents initially targeted to the telecommunications domain. In our research, we observed that by explicitly representing feedback loops we could identify areas that run the risk of starting a cascade of consequences in a positive feedback loop, causing even more damage to the organisation.

We observed that splitting the group according to expertise is counterproductive and we identified business capabilities that may form a basis for a maturity model for business continuity for telecommunications. Furthermore, we proposed to obtain a sponsor at senior management level to ensure cooperation from the organisation.

Further research into capability maturity models for Business Continuity Management can give new insights into ways to prioritise recommendations. Fitting the recommendations for crisis management to a crisis management framework may also give new insights into prioritisation. Our clustering of recommendations can be seen as a first proposal for the capabilities needed for business continuity for telecommunication companies, both from the aspects of preventing an accident that threatens business continuity and from the aspect of crisis management. The adequacy of the clusters and their applicability as a means for prioritising recommendations also merits further research. Future research can also apply advanced data analytics to the analysis of the recommendations, such as clustering techniques based on NLP for discovering new capabilities. Finally, future research may show the effect of senior management level involvement on the prioritisation of the recommendations and staff involvement.

REFERENCES

Branford, K., Naikar, N., and Hopkins, A. (2009). Guidelines for accimap analysis. In Hopkins, A., editor, *Learning from High Reliability Organisations*, chapter 10. CCH Australia Ltd.

Hollnagel, E. (2002). Understanding accidents-from root causes to performance variability. In *IEEE 7th Human Factors Meeting*, pages 1–1 – 1–6. New Century, New Trends. Proceedings of the 2002 IEEE 7th Conference on Human Factors and Power Plants.

Hollnagel, E. and Goteman, O. (2004). The functional resonance accident model. *Proceedings of cognitive system engineering in process plant*, 2004:155–161.

Junttila, J. (2014). A Business Continuity Management Maturity Model. Master's thesis, University of Turku.

Lacerda, T. C. and von Wangenheim, C. G. (2018). Systematic literature review of usability capability/maturity models. *Computer Standards & Interfaces*, 55:95–105.

Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, 42(4):237–270.

Mahal, A. (2008). Business Continuity Management Maturity Model for Banks in U.A.E. Master's thesis, The British University in Dubai.

Maier, A. M., Moultrie, J., and Clarkson, P. J. (2012). Assessing Organizational Capabilities: Reviewing and Guiding the Development of Maturity Grids. *IEEE Transactions on Engineering Management*, 59(1):138–159.

Malone, N., Hernandez, M., Reardon, A., and Liu, Y. (2020). Advanced Distributed Learning Capability Maturity Model. Technical report, US Department of Defense — Defense Human Resource Activity.

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety science*, 27(2):183–213.

Reason, J. (1990). The contribution of latent human failures to the breakdown of complex systems. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, 327(1241):475–484.

Reis, T. L., Mathias, M. A. S., and Oliveira, O. J. d. (2017). Maturity models: identifying the state-of-the-art and the scientific gaps from a bibliometric study. *Scientometrics*, 110(2):643–672.

Salmon, P., Goode, N., Lenne, M., Finch, C., and Cassell, E. (2012). Understanding accident causation in led outdoor activities: development of an accident analysis framework. *Injury Prevention*, 18(Supplement 1):A240–A240.

Smit, N. (2005). Business Continuity Management - a Maturity Model. Master's thesis, Erasmus University Rotterdam.

Vesely, W. E., Goldberg, F. F., Roberts, N. H., and Haasl, D. F. (1981). Fault tree handbook. Technical Report 0492, U.S. Nuclear Regulatory Commission.

Wienen, H. C. A., Bukhsh, F. A., Vriezekolk, E., Fereira Pires, L., and Wieringa, R. J. (2024). Squeezing the lemon: Using accident analysis for recommendations to improve the resilience of telecommunications organizations. Accepted for publication in ICEIS 2024.

Wienen, H. C. A., Bukhsh, F. A., Vriezekolk, E., and Wieringa, R. J. (2018). Learning from accidents: A systematic review of accident analysis methods and models. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, 10(3):42–62.

Wienen, H. C. A., Bukhsh, F. A., Vriezekolk, E., and Wieringa, R. J. (2019). Applying generic AcciMap to a DDoS attack on a Western-European telecom operator. In *Proceedings of the 16th ISCRAM Conference*, pages 528–535.

Wieringa, R. J. (2014). *Design Science Methodology for Information Systems and Software Engineering*. Springer.