Formalization of Crisis Response Coordination from a Public Inquiry Report

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ABSTRACT

We assess the usability of public inquiry report data to build a formal trace that can be used in later stages to create an agent model simulating crisis response coordination. The case taken is a train tunnel fire near the underground train station at Amsterdam Airport Schiphol that turned out to be harmless, but the incident illustrated key weaknesses in inter-organizational coordination causing a slower response than required in case of a more serious fire. We present a taxonomy of data problems resulting from our attempt to reconstruct a logical series of events. This highlights gaps or ambiguities in data pertaining to coordination practices, communication networks, situational properties and information and communication systems. Our formal trace cannot support all the report's claims that explain the failures in coordination. The report data show some critical problems, but can still serve as a basis for an information network model of the crisis.

Keywords

Crisis coordination, data formalization, data analysis, information networks, public inquiry report.

INTRODUCTION

Getting reliable data is often a problem in crisis research, so it is worth scrutinizing whatever data are accessible. Observations, transcripts and retrospective interviews provide a solid basis for analysis, but access or resources to secure these data may be lacking. A public inquiry report is an alternative data source that can provide valuable insights, but contains potential gaps and errors that must be filtered out. By exploring one case, we present a methodological discussion of how public inquiry report data can be valuable for crisis research.

The case discussed is about a small fire in the Amsterdam Airport Schiphol underground train tube in the afternoon rush hour of July 2nd 2009 that had catastrophic potential [1]. As smoke from the fire spread throughout the tunnel, miscommunications between railroad and fire fighting parties critically delayed the evacuation of thousands of passengers. Preceding this situation, emergency services were mobilized in an inconsistent manner as operational decision makers interpreted the early signs of smoke and fire differently. When the first emergency services arrived on the scene, a few officials recognized that following the complex set of existing standard procedures would impede a quick response. They improvised a faster coordination by sometimes bypassing the multitude of control rooms involved in the official procedures. Yet they sometimes misunderstood each other and were not always able to gain and share proper understanding of the situation. As a result, three trains full of passengers were kept in the burning tunnel for over half an hour. As it turned out, the fire posed a limited threat because it ran out of fuel. However, the explosive dynamics of a more serious tunnel fire can become life threatening within ten minutes. The authorities realized that the response of the current incident would be far too slow to ensure the safety of thousands of passengers transported daily through the tunnel. Consequently, the Dutch inspection for transportation (IVW) and the inspection for public safety (IOOV) jointly conducted an investigation to find the causes of the failed coordination and provide recommendations [1].

Our central question is: how well are the data of this report suited to construct a formal trace of the unfolding communication network in which the crisis coordination problem can be explored? The aim of this paper is twofold. We first want to question how evaluation reports can be used for the formal analysis of safety of response networks. Second, we would like to reflect upon the quality of the evaluation report to come up with recommendations for the inspectorate. This paper continues as follows. In the next section, we explain our approach to the formalization of the report data. Then, we present a taxonomy of data problems. In the discussion, we illustrate how we dealt with them. In the conclusion, we assess the value of the data and evaluating explanatory claims made elsewhere.

APPROACH

The formalization of relevant concepts into a so-called trace allowed us to gain detailed insight in the coordination dynamics of the crisis. The formalization process amounts to translating the mostly qualitative data into a computer-readable format that enables dedicated software tools to reason about the data. This forces the analyzer to reconstruct the events in a much more exact manner than they were be described in the public incident report. The resulting format is a combination of statements of quantitative and logical nature.

In order to create such a formal trace, it is necessary to identify relevant actors and events and to define an ontology of the concepts needed to describe the situation. For example, in this translation process, the alarms of smoke or fire were molded to statements about communication from one agent to another agent, consisting of an estimation of the severity and a location of the signs. Any other information (such as concrete terminology) cannot be represented within this ontology. This implies that certain elements like exact wording could be missing or are too complex for formalization. In such situations, it may be necessary to convert the data to more abstract concepts. For example, in the final trace, all location terminologies are transformed into our ontology, such as “tunnel2A” for the part of the tunnel where the fire source was located and “tunnel1A” for the parallel tunnel tube from where the fire fighters entered. By this means, the data are abstracted from personal wordings to generic and analogous concepts. In such formalization decisions, it is important to maintain the right balance between the need for transformation and possible costs of losing details of the data.

The course of events during the incident in the Schiphol tunnel is formalized in the software tool Leadsto [2]. This program allows for representation of both quantitative and logical data. Figure 1 is a screenshot of a fragment of the resulting trace. It shows that the trace consists of a series of time intervals in which certain events take place, which are either *world states*, *observations*, *communications* or *actions*. This example shows the communications from time point 102 to time point 104. Each time point in this particular trace represents half a minute, starting from 17:25h at t = 0. Thus, Figure 1 shows the events between 18:16h and 18:17h.

```
⊟──interval
      ├──R: range(102, 104)
      ⊟──F and
            ├──communication_from_to(ProRail_EOC, RTC2, request(info(at_location(trains(two, holding), tunnel2A))))
            ├──communication_from_to(RTC2, ProRail_EOC, at_location(trains(zero, holding), tunnel2A))
            ├──communication_from_to(RTC2, ProRail_EOC, sign_clear(trains))
            ├──communication_from_to(ProRail_EOC, RTC2, intention(FE340, enter(tunnel2A)))
            └──communication_from_to(ProRail_EOC, RTC2, intention(FE341, enter(tunnel2A)))
```

Figure 1. Fragment of formal trace.

The resulting trace provides information about the incident in an unambiguous format that can be further analyzed by automatically checking complex properties; this will be done in later stages of the research process. A property is a logical statement about information in the trace, for example if there are more communications between actors of the same organization than between actors of different organizations. Properties are defined in Temporal Trace Language (TTL) [3]. In Leadsto, these TTL-properties can be automatically checked to be true or false for the given trace. This helps one to easily check complex properties that are difficult to verify manually. Next, the trace can serve as input for the development of a model of interactions between actors. In addition, the trace can be used for validation of such a model by comparing its output to the actual course of events. If the actual events are reproduced by the model, this supports its usability and the reliability of its predictions.

PROBLEMS WITH THE DATA

During the formalization process, a number of problems with the data arose, but by tracking gaps and errors that we found in the data, we made sure that we only used what data we could trust. Some data were incomplete, other inconsistent. The problems were categorized in a taxonomy (Table 1) that we explain below.

PROBLEM CATEGORY	TYPE	LABEL
COORDINATION PRACTICES	PLANNED/ROUTINE UNDERSTANDINGS	COMMAND STRUCTURES
		STANDARD OPERATING PROCEDURES
	EMERGENT PATTERNS	(INTER)ACTIONS BETWEEN ORGANIZATIONAL LEVELS AND UNITS
		(INTER)ACTIONS WITHIN ORGANIZATIONAL UNITS
COMMUNICATION NETWORKS	COMMUNICATING ACTORS (NODES)	ORIGIN AND FLOW OF INFORMATION
		KNOWLEDGE OF ACTOR ATTRIBUTES
	COMMUNICATED INFORMATION (LINKS)	MESSAGE SENT BY SENDER
		MESSAGE RECEIVED BY RECEIVER
SITUATIONAL PROPERTIES	TIME AND SPACE	TIMING AND DURATION OF MOVEMENTS
		GEOGRAPHICAL/SPATIAL LOCATION OF ACTORS
	INFRASTRUCTURE	FUNCTIONING OF (RAILWAY) ELECTRICAL SYSTEMS
		LOCATIONS OF EMERGENCY EXITS/ENTRANCES/SPACES
INFORMATION AND COMMUNICATION SYSTEMS	SYSTEM-HUMAN INTERFACES	FORMAT OF SYSTEMS MESSAGES
		FORMAT DISPLAYED ON SCREENS OF A CONTROLLERS
	INTEGRATION OF SYSTEMS	SHARING OF COMMUNICATION CHANNELS WITHIN SYSTEMS
		OPERATOR ACCESSIBILITY BETWEEN COMMUNICATION SYSTEMS

Table 1. Taxonomy of data problems.

Coordination Practices

Coordination practices encompass both routine and emergent patterns [4]. The events between 17:49h and 17:51h exemplify where routine and emergent coordination data are ambiguous. The decision was made to hold three trains in the burning part of the tunnel, rather than drive them out immediately. Locally at Schiphol, the Airport Fire Officer (AFO) commands the first response. At 17:49h, he requested, through an emergency dispatch center we call DC_SR_K, to direct the trains out which were holding in the burning part of the tunnel. The request was passed on to the railway infrastructure company's Emergency Operations Coordinator (EOC), responsible for crisis coordination between fire fighting and railway parties. However, the EOC requested the Railway Traffic Controller (RTC) to *hold* the trains so fire fighters could explore to find the fire. The RTC objected that perhaps the fire fighters would prefer to have the trains out first, but the EOC maintained that fire fighters were already in the tunnel and they could not make clear where. The RTC conceded and the EOC proceeded to inform the AFO that his men could enter, though three trains were still holding in the tunnel. Rather than asking why his request had not been tended to, the AFO acknowledged the message and continued to order two crews in the adjacent tunnel tube to the one on fire. We could speculate that procedures used by operators at DC_SR_K in the context of the chaotic situation warped the AFO's original request, but there is little data on interactions inside control rooms. We decided not to include this in the trace: the AFO's request to vacate the trains is simply met with the opposite response to hold the trains.

Communication Networks

As the report describes communications concisely in the third person, and leaves many communications out altogether, it is often unclear how the communication network unfolded. In this category, we had problems of two types. First, data in the form of communication nodes – people or groups who communicate – and second, the links between them: the communications. We again refer to the example where the EOC orders three trains to hold when the AFO requests the trains to be driven out of "the tunnel tube". Data are ambiguous as to how that message was sent, relayed and received. The recipient of the message, the EOC, may have been unaware of what the exact location was the AFO referred to. While we gave different subsections of the tunnel specific designations in the trace, the AFO and the EOC apparently did not share a joint vocabulary. The EOC based the decision to hold the trains on his concern about fire fighters who could not tell exactly where in the tunnel they were. It is not mentioned where that information originated from, only that it led to a false interpretation. The fire fighters were in fact safely on the platform waiting for permission to enter the tunnel tube adjacent to the one on fire.

Situational properties

We found problems with time and space and lacked information about infrastructural aspects. With respect to time and space, timing of certain events showed slight discrepancies in different points of the report, and we usually had to guess the duration of actions and interactions. Also, the geographical location of actors like the fire fighter crews that headed into the tunnel is not entirely clear. For example, the report mentions a conductor overhearing a conversation between a fire fighter and his commander, but it is unclear if this contact occurred in physical proximity or that they shared a communication channel. As for infrastructure, the location and physical existence, size and shapes of connecting spaces between tunnel tubes that would have been necessary for this contact are unclear. For example, in the report there is an inconsistency between the analysis section and the appendix about the movement of a train. In addition, although the protocols applying to the situation are discussed, it is not clear whether the railway overhead power lines were disarmed for safety when the fire fighters entered the tunnel. That would have implied the trains standing still were not only holding still by command –which due to a feared mutiny on board might have been violated– but by immobilization. Knowledge about this status of the railway system may have influenced decision making by the AFO and EOC but cannot be included in the trace.

Information systems

Limited information was available on information and communication systems, in particular on interfaces with controllers and the degree to which different systems in use were integrated. Some control rooms sent out automated messages, but we usually could not discover what would typically be included in such a message. The operators present would have had a computer display with which they could access information, which influences what they know, and how information travels through the network. The contact between fire fighters and the train conductor must have been by physical proximity if we would know that the emergency services communication systems and that of the railway excluded each other. In the railway system, we do not know whether train conductors can hear other conductors talk. That hampers our ability to judge what information these actors had access to.

DISCUSSION

At the heart of our formalization dilemmas was the question: did we risk losing data categorizing it at a higher level of abstraction, and would the generalization it represented be useful? We developed a simple method to make the transition from opaque, official writing into abstract code. In the first stage, we drew a communications diagram with all communications. In the second phase, we translated and amended this diagram to Leadsto code. By constantly identifying problems and debating about them, we made various ambiguities and discrepancies explicit. Thus, we could determine what we could reliably reconstruct, and exclude what we could not be sure of.

A single utterance could be worded differently in each of the three narratives by which the report recounts the events from different points of view. Yet for making the trace, they had to be molded to abstract categories both supported by evidence and serving the purpose of the trace. In the first stages of the crisis, for example, numerous actors call various control rooms to signal their concern about smoke filling the station and the tunnel tubes. However, the details of the communications were inconsistent or absent in the different narratives in the report. We resolved this problem by categorizing the utterances in an iterative process and checked if it made sense across the trace. Once the trace reflected the order of events as mentioned in the incident evaluation report, we concluded that there was sufficient validity in the construction of the trace.

In a similar way we were able to resolve most of the problems with the exception of the interaction between the AFO, DC_SR_K, EOC and RTC mentioned before. Another report by Helsloot et al. [5] refers to the IVW and IOOV report at this moment in time to support a particular claim. They interpret the events as an effect of a systematic tendency by Dutch emergency services to favor safe passage for responders to help victims over quick evacuation of the victims by any means available. We would expect that such a systematic property should figure prominently in a formal trace, as it would be an important characteristic of the model. Further research and subsequent network modeling may be used to validate this explanation and explore alternative sets of emergency responses.

CONCLUSION

We conclude this paper with two points that mirror the two aims of the paper.

First, we found that while our case study found various problems with the data quality of a public inquiry report to model the coordination process, it still allows one to use the data for a more formal analysis of safety of response networks. That is, our formal trace captures and tracks some basic communicated distinctions and agent responses as the crisis unfolds. The formalization effort led us to focus on particular interactions and their role in our reconstruction of the events. This allows for an alternative explanation of the failing coordination process. Rather than attributing failure to the complexity and ambiguity of available procedures, our trace shows a failing information network resulting from the sensemaking efforts of its participants.

Second, our work-in-progress may have consequences for writing public inquiry reports. It may well be that report writers are limited in what data they can present due to legal and political limitations. However, our judgment of the presented data is that they cannot support the report's analysis formally. Other research building on the report then falls prey to the same problem. To mend this problem, a public inquiry report would need to include more data on organizational practices, communication networks, situational properties, and information and communication systems.

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