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Sensing the breakdown: managing complexity at the railway

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ABSTRACT
This paper explores the complex and time-critical work practices within operational train traffic in Sweden by reporting on an incident causing an infrastructure breakdown and large traffic disruptions. Based on a workplace study approach, we report on how the control room workers – train traffic controllers and information officers – grasp, make sense of, and handle the consequences of the incident as it unfolds in real-time. We portray how the workers develop and acquire a sense of place in relation to the incident’s severity which is essential for successfully handling the situation. By introducing the ‘sense of place’ concept originally derived from the field of natural resources to the domain of operational train traffic, we provide a deepened understanding of the challenges characterising remote control work from a safety-critical socio-technical systems perspective. Finally, reflections on the application of the ‘sense of place’ concept, safety aspects and directions for future research are provided.

1. Introduction
In this paper, we report on an incident in the train traffic domain: a torn-down electrical wire causing an infrastructure breakdown and a large traffic disruption. We will follow the handling of this incident as it unfolds from within the control room for operational train traffic to investigate and analyse how the workers manage to make sense of and handle this unexpected and time-sensitive event. With the workers’ overarching goal being to mitigate the consequences of the incident and get the train traffic running as soon as possible in a safe, efficient, and smooth way, we portray how they repeatedly coped with challenges related to time and space. This pointed us to explore the concept ‘sense of place’ to better understand the work practices at the core of the remote control work in which the workers experience, and create a meaning of, the place of the incident without being there physically (Raymond, Kyttä, and Stedman 2017; Relph 1976). The emphasis on the meaning attached to a place, as offered by the ‘sense of place’ concept, provides additional views that practice theories have not paid much attention (Kuutti and Bannon 2014). Accordingly, the main contribution of this paper is insights into work practices where the technological development allows the workers to experience and be involved in a place without being physically there, which adds to the previous body of knowledge on remote control room work.

Our research is influenced by distributed socio-technical systems approaches to study the work practices for handling the incident (e.g. Heath and Luff 1992; Hollan, Hutchins, and Kirsh 2000; Hutchins 1995; Kuutti and Bannon 2014; Luff et al. 2018; Orlikowski 2007; Suchman 1987; 1997; Szymanski 2000; Szymanski 2006; Tjosvold et al. 2000; Tjosvold and Szymanski 2000). Our study provides a deeper understanding of the challenges characterising remote control work from a safety-critical socio-technical systems perspective. It offers insights into the work practices where the technological development allows the workers to experience and be involved in a place without being physically there, which adds to the previous body of knowledge on remote control room work.

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and Whalen 2011; Wilson 2014; Wilson et al. 2007). These approaches focus on the complex interplay between people, artefacts, and technology distributed in space and time, emphasising the details of how interconnected activities are accomplished in natural settings of work. They are aligned with a body of research that studies the course of actions carried out in the workplace where these work practices become more visible. The above socio-technical approaches consider work holistically, going beyond the traditional view of the socio-technical system as two side-by-side systems that are inclined to either a technology push or a turn towards the social. Accordingly, the relationship and interdependence between technology and the social entails or enacts each other in the core work practices of the distributed socio-technical system (cf. e.g. Hollan, Hutchins, and Kirsh 2000; Hutchins 1995; Lebahn-Hadidi et al. 2023; Luff et al. 2018; Orlikowski 2007; Wilson 2014; Wilson et al. 2007).

Operational train traffic takes place in a setting where collaboration between skilled human workers and technologies is crucial, it is often time-critical and requires the workers to predict and interpret what others will do and how a certain situation will develop itself. The organisation of work is complex, involving multiple organisations and actors. Train drivers operate their trains in a messy environment that frequently presents them with factors out of the drivers’ control, e.g. weather conditions affecting the trains or the infrastructure, or geographical peculiarities to which they need to adapt their driving behaviour. The involved control room operators are continuously oriented to coordination problems in relation to time and space due to the subject of control (i.e. the trains) being out of their physical reach. This creates an information-dense work environment in which they depend on various representations as well as analogue and digital artefacts to interpret and handle current traffic situations. There is no room for ambiguity in regards to the situation at hand, but a vast number of information sources puts a lot of cognitive strain on the workers’ ability to puzzle together pieces of disparate and often incomplete information in order to act adequately in response to the emerging situation (cf. Suchman 1997). Earlier qualitative studies on operational train traffic have shown how the workers are faced with recurrent challenges related to time and space as well as collaborative and coordinative aspects of work between not just traffic controllers but between controllers and drivers (Andreasson, Jansson, and Lindblom 2019a; 2019b; Cort 2020; 2021; Luff et al. 2018; Naweed 2020; Wilson and Norris 2006). Additional work has studied how the embodied and sensible nature of knowledge of train dispatchers’ work in a railway control room can be characterised as a kind of ‘attunement,’ in which dispatchers become more skilled in aligning their bodies and senses in handling practical situations from the organisational and management learning perspectives (Willems 2018). Others have studied how a team of railway coordinators use their sensemaking ability to handle an upcoming and unexpected event like an approaching winter storm. Their study revealed how the coordinators collectively made sense of the disruptiveness of the upcoming storm. It was shown how collective sensemaking developed as a shared or a negotiated process where temporal and contextual factors were central from an organisational change management perspective (Merkus et al. 2017).

What separates the current paper from the previous train traffic research is its focus on the inter-related and coordinated work process of several professional roles while handling an incident in real time from a distributed socio-technical systems perspective. Investigations of accidents, emergencies, and disasters are normally conducted in retrospect (e.g. Comfort 2007; Mills and Weatherbee 2006; Weick 1990), but in this paper, we report first-hand from inside the control room for operational train traffic to display the work practices involved in handling the incident as it unfolds in real time. For example, Dekker (2015) points out that studies on how professional workers handle critical situations as they naturally unfold are rarely given deserved attention in research. In organisational studies, the seminal article by Weick (1988) has highly impacted how sensemaking is viewed as a way to address the way crises are enacted in organisations rather than something that workers simply encounter. Although this tradition has received much deserved attention, the sensemaking perspective is still lacking an explicit focus on the meaning of place in situations handling remote work in the control room, in which operators are continuously oriented to coordination problems in relation to time and
space. In this paper, we provide a deep understanding of how the workers in operational train traffic handle an incident of a freight train getting caught in the overhead wire, as the situation unfolded in situ.

There is an identified need to study how work is done from a cognitive distributed systems perspective (cf. Hollan, Hutchins, and Kirsh 2000; Hollnagel, Wears, and Braithwaite 2015; Hutchins 1995; Lebahn-Hadidi et al. 2023; Leveson 2020). Aligned with this perspective, it is emphasised that the workers are situated within a distributed socio-technical system where the system has to be designed in ways that allow for the workers to act in a flexible way to handle unexpected events, addressing the acquired implicit and embodied knowledge of the workers within the organisation. Most reports on incident handling generally tend to stress what should have been done rather than what was actually done and attended to by the professional workers in situ (Lebahn-Hadidi et al. 2023). We, therefore, report on how an incident of a torn down electric overhead wire, that resulted in large disruptions of the train traffic, was handled remotely from the control room as the situation unfolded in situ.

2. Sense of place

We employ the ‘sense of place’ concept to explore its applicability to the work of remote traffic control. The concept originates from the field of natural resources and has traditionally been used mostly within the agricultural, landscape, and geographical domains (e.g. Cheng, Kruger, and Daniels 2003; Eaton et al. 2019; Raymond, Kyttä, and Stedman 2017; Relph 1976; Stedman 2003) but recently it has also been applied to virtual reality (Tjøstheim 2020) and office workscapes (Wilhoit Larson 2021). The concept broadly describes the human connection to places, and it is characterised as the cognitive, affective, and attitudinal relationships between humans and certain places (Eaton et al. 2019). Accordingly, the ‘sense of place’ concept differs from the conceptualisation of space in regards to having a certain meaning and relationship beyond the mere spatial position. The concept may provide insights on how to handle the coordination paradox as a work practice when there is no localised centre of attention (Suchman 1997) but instead distributed to the periphery of activities, tasks and operations performed by the control room workers in a distributed socio-technical system. This is our motivation for introducing the ‘sense of place’ concept in the setting of de-centralised control room work practices.

Without going into the different strands of the conceptualisation of sense of place, we apply the view described by Raymond, Kyttä, and Stedman (2017) in which they describe place as a ‘center of meaning’ (for further details about the concept, see e.g. Eaton et al. 2019; Raymond, Kyttä, and Stedman 2017; Relph 1976). This is well-aligned with the more interpretative and meaning-making approaches of how to consider the human actor being situated in its physical, material and socio-cultural environments (Kuutti and Bannon 2014; Lebahn-Hadidi et al. 2023; Merkus et al. 2017; Suchman 1987; 1997; Willems 2018) where the emphasis on the sense of place focuses on characterising meaning and relationships to certain places in more qualitative terms. Following this line of argument, the development of a sense of place does not only relate to a physical location along the rail or at platforms but is also shaped by how the situation is experienced first-hand from within the control room as a locus for carrying out meaningful actions. Hence, the ‘sense of place’ concept is here used to describe how these meaning-making and sense-making processes are manifested, and sometimes collectively distributed, shared, and deployed among the workers in the control room. In so doing, a sense of place emerges through prolonged practice with the support of additional resources, which are both materials in the form of various analogue and digital cognitive artefacts and external qualities of the critical situation retrieved from train drivers and repair workers being situated ‘here and now’ at the location of interest.

3. Method

The incident at the centre of this paper is a true case taking place in the northern parts of Sweden. The setting for the paper is thus Swedish operational train traffic, which includes all tasks associated
with the realisation of the traffic, such as train traffic control, train driving, customer information, infrastructure maintenance work, and operational planning such as resource allocation at the railway undertakings (Trafikverket 2018). The organisation of work in the Swedish railway system is decentralised with one infrastructure manager and multiple railway undertakings. The infrastructure manager is in charge of traffic control and customer information, which takes place within control rooms geographically distributed across the country, while the railway undertakings and their train drivers are in charge of operating the trains.

It should be mentioned that this study draws on a collection of workplace studies from the context of operational train traffic, in which the first author has conducted extensive fieldwork during a time period of 2.5 years. Approximately 150 h of ethnographic data were collected during this time in which the work of both train traffic controllers, information officers, and train drivers were the object of study. To spend time in the field had enabled the first author to learn about the domain, the workers, jargon, and artefacts used and to uncover nuances of the work practices in a way that would not have been possible without this engagement over time. This relates to what Moeran (2009) describes as moving from a participant observer to an observant participant. From this pro-longed time frame, the first author has created a relationship of trust with the workers and gained an engagement with, and understanding of, their interactions with each other and accompanying technologies within the social and cultural context of the distributed socio-technical system of the train traffic control room.

In line with the distributed socio-technical systems approaches to studying work practices, workplace studies were the chosen methodological approach. Workplace studies aim at studying, discovering, and describing the problems and taken-for-granted competences involved in how workers accomplish various tasks (Heath et al. 2000; Luff, Hindmarsh, and Heath 2000; Rawls 2008; Sellberg and Lindblom 2014). Hence, making work practices visible (Szymanski and Whalen 2011). Workplace studies collect various kinds of ethnographic data involving a combination of ethnographic fieldwork of observation, participation, and informal interviews to provide rich insights about work practices and also how technology is integrated into the social and cultural dimensions of the workplace (Dourish and Bell 2011).

This paper is based on our previous writings, in which we have depicted work practices in operational train traffic through the lenses of theoretical perspectives highlighting the culturally, situated, and cognitively distributed nature of work (e.g. Andreasson, Jansson, and Lindblom 2019a; 2019b; Cort 2020; 2021). This is in line with the authors’ background in situated and distributed cognition, which brings an interest for how meaning emerges in the interaction between humans and their social and material environments (e.g. Gallagher 2006; Hutchins 1995; Lindblom 2015), which is an interest we take on as a guiding principle in all our research. In this paper, the emphasis will be on a specific incident as such, how it unfolded and how the workers handled the situation, rather than on viewing the incident through a selected theoretical filter. Our research approach is, thus, empirically driven and the challenges and contingencies observed in the work situation led us to include the ‘sense of place’ concept. We will employ our interpretation of this concept as a way to gain insights into the work practices at the core of how the incident was handled. Our argument for this is based on the premise that the traffic controllers and information officers, socially and physically situated in the control room, have developed and acquired relationships with the railway as well as the platforms and stations that are, at least in part, qualitatively distinct from the experiences of those being physically located at these places, such as train drivers and travellers.

During ordinary data collection, it is rare to capture incidents like the one explored here due to their unexpected nature. However, at the time of this incident, the first author was present in the control room from which the incident was managed and so this paper provides novel insights into how the incident was handled as it unfolded in real-time. Participant observations and informal interviews were used to capture nuances and obtain a rich understanding of the work practices under study. The main focus is on the control room work and, thus, the professional roles of traffic controllers and information officers working therein. The train drivers are occasionally
mentioned since they play an important part in operational train traffic, although they were not observed during this particular incident.

Both traffic controllers and information officers, four workers in total, involved in the handling of this incident had extensive experience working within operational train traffic. Their experience ranges from approximately 8–20 years and at least two of them had complementary knowledge from holding other positions than their current ones, which provided them with a thorough and holistic understanding of the control room work and operational train traffic in large. The two traffic controllers both had 10 to 12 months of training in the shape of theoretical lectures about the traffic control task, the signalling system etc., parallel to hands-on training in the control room while supervised by an experienced traffic controller. They were also continuously undergoing tests of perceptual, psychological, and cognitive nature as a result of the traffic control task being very cognitively demanding. In comparison, the training that the information officers had undergone was much shorter, covering approximately two weeks of training in total, out of which most of the time was performed as hands-on training in the control room. However, both information officers in this study had extensive experience of working with travelling information and one of them had previously worked as a traffic controller for roughly 15 years. These workers will hereafter be referred to as Jack, Sarah, George, and Anna, which are all fictitious names and with no resemblances to the participants’ real names. This study was carried out in accordance with institutional guidelines, with informed consent from all participants in accordance with the Declaration of Helsinki.

It should be noted that it is not possible to describe the complete chronological narrative of the incident and how it unfolded due to the spatially distributed nature of work in operational train traffic. This is an issue of time and space affecting everyday work in this setting. We therefore focus on a selection of excerpts from three phases of the collected data that was central to how the control room work unfolded, was coordinated, and enacted to manage the complexity of the breakdown caused by this incident. All the data were closely captured using descriptive field notes, with the purpose of creating information-rich data during the observations in the control room. This, along with e.g. instruction materials, checklists, incident reports etc. has been essential for examining and understanding the work practices involved in handling the incident. Neither photographs, audio, nor video recordings were allowed in the control room due to security regulations and so the collected data consists of detailed field notes, including descriptions of the environment, quotes from participants, questions asked and their answers, and much more. Furthermore, the empirical material of this study also draws on our previously acquired knowledge and experience of conducting research in the context of Swedish operational train traffic.

The analysis of the empirical material begun already in the control room during the fieldwork by the researcher continuously moving between learning and checking what has been learned, in accordance with the ethnographic research tradition (Agar 1996). In this process, the informal interviews greatly contributed to insights into the workers’ perspectives and brought a better understanding of the nuances of the activities that were observed. The analytical work continued and took on a more systematic form as the fieldwork ended and followed the thematic analysis approach as described by Braun and Clarke (2006). This process started with repeatedly working with the data, reading the fieldnotes actively and analytically in purpose to become familiar with even the smallest nuances of the dataset to be able to move beyond the surface and to start identifying what the data actually mean. In this process, we assigned codes to units of data, analysed these for meanings and patterns to identify emerging themes and theoretical insights. This was done as an iterative analysis process, meaning that we repeatedly returned to the data for further coding and analysis in light of the emerging themes and insights. We triangulated the different data sources to construct a chronologic narrative describing the unfolding of the incident, including the main actors, their point of views, and other important aspects of relevance for the narrative.

The analysis resulted in a detailed story describing the incident with the torn-down overhead wire and how the control room workers grasp, make sense of, and handle the situation. In this story, it was repeatedly revealed how the workers had to cope with challenges related to time and space.
Accordingly, the ‘sense of place’ concept was used to explore its suitability for better understanding the work practices at play in remote control work when handling an incident causing a breakdown of both the infrastructure and the traffic flow. This type of empirically driven research, making use of theoretical constructs as they offer support for the analysis without the restrictions of staying truthful to one selected theory, is much in line with previous works by, for example, Lucy Suchman (e.g. 1987; 1997). To move beyond mere descriptions, we were also inspired by Merkus et al. (2017) who applied the ‘temporal bracketing’ strategy as described by Langley (1999). We ‘bracketed’ the incident into three continuous phases to illustrate how the incident was handled as it unfolded and how the circumstances and information available affected the handling of the event by the train traffic controllers and information officers situated in the traffic control room. These temporally bracketed phases became our main unit of analysis and each phase needed to be different from the other while having internal consistency and continuity. Both authors gathered and discussed the identified phases, their meanings and differences in interpretation until an agreement was reached. We then interpreted the different phases of the incident in terms of relevant concepts from distributed socio-technical systems and the ‘sense of place’ concept to gain further insights into how the work unfolded, was coordinated, and enacted to make sense of the complexity of the breakdown caused by this incident.

4. Findings

Below, we report on the unfolding of an incident in which a torn-down electrical overhead wire causes an infrastructure breakdown and a large traffic disruption with multiple trains getting delayed or cancelled. The organisation of work is distributed among a number of workers, across time and space (Figure 1).

4.1. Grasping the incident

The incident takes place one early morning, around 5 am, in October and from the perspective of the control room work, it all started with a phone call to the traffic controller. For the purpose of this paper, the traffic controller working the morning shift will be referred to as Jack. It was a slow morning, as they usually are at this time of day but once Jack receives the phone call from the

Figure 1. Visual representation of the unfolding of the incident with respect to the roles involved and the main activities conducted in order to grasp, make sense of, and handle the consequences of the incident. It should be noted that the visualisation is representative of the order of activities and not the duration of each phase of the incident, and also that the same activity can involve several persons.
train driver a long row of activities is initiated. The train driver is calling to report on an incident in which his train has accidentally torn down the electric overhead wire leaving the train without power. Few trains in Sweden are equipped with motors or a local fuel supply. Instead, they make use of electricity supplied via conductors running along the tracks in an overhead wire. The train driver involved in this incident describes how this overhead wire must have broken without him realising it and as the train continued to run, the wire twisted itself around the train cab.

As soon as Jack realises the reason for the train driver’s call, he initiates a row of multiple tasks. He starts to wave his hand in the air to get the attention of his colleagues and especially his manager who has the overall responsibility of all traffic control decisions made in this control room. The manager is normally engaged in monitoring the work activity in the control room but in situations out of the ordinary, he should be actively involved in making strategic decisions and supporting the traffic controller in all ways possible. When Jack’s waving hand gets the manager’s attention, Jack is still on the phone with the train driver. The manager walks over to Jack and listens in on the phone call. While talking to the driver, Jack is visually searching the graphical interface of the digital traffic control system (Figure 2) for the identification number representing the train from which the driver is calling. This system displays representations of the railway, signals, and switching points and through this system, Jack monitors the traffic in real-time while he manually controls the switches and signals (for more details on the traffic control system, see Andreasson, Jansson, and Lindblom 2019a; Cort 2020). Locating the train in the traffic control system reveals its exact position, and thus the geographical position of the incident. Jack starts to manually set all signals in the affected area to ‘stop’ to hinder other trains from getting near the site of the incident. The voltage in the overhead wire is 15,000 volts and since it has been broken, getting close to it can be life-threatening. For this reason, Jack decides to also switch off the power supply to the whole area in which the train is located. These actions are all manually performed in the traffic control system.

These initial actions aimed at restricting others’ access to the affected area, take just a few seconds and once they are done and the area is secured, Jack relaxes a bit and tends to the conversation with the driver who is still on the phone. He starts to interview the train driver and asks for as much information as possible about the situation and its severity. The digital traffic control system does not offer much support in this endeavour since it only presents a rather unrealistic representation of the rail, the trains, and their current locations. To be located in the control room means that all traffic control work is remote and the workers never see the physical objects their work is directed towards, i.e. neither the rail, trains, nor travellers are in plain sight from the control rooms. In this case, Jack and his colleagues are located approximately 150 kilometres away from the site of the incident. To get information about something taking place outside the control room, the traffic controller is heavily dependent on the train driver situated at the scene. The driver, as the only one physically situated at the site of the incident, is the main informant and the one who needs to gather and communicate first-hand information about the situation. Already when Jack locates the train’s position, he starts to develop a sense of place enabling him to grasp the incident within its environment. This is then further developed as he interviews the driver to gain a second-hand experience of the site. The interview enables him to interpret and construct meaning of the place without physically being there, which helps him conceptualise the incident and its surrounding factors.

Jack uses a checklist to make sure that all relevant information from the driver is carefully documented. The gathered information enables Jack to assess the severity of the situation and to decide on how it best should be handled. The driver is slightly shocked and keeps repeating that he does not know how this happened. He describes how the electrical wire has twisted itself around the cab, which is when he noticed that the wire must be broken. Once he realised this, he immediately stopped the train and called the traffic controllers (and based on his geographical position, his call automatically reached Jack who is in charge of the traffic in this particular area). Jack instructs the driver to sit tight in the cab and wait for further instructions.
Approximately 10–15 min have passed since Jack first answered the phone and as he and his manager start to get an initial grasp of the situation, the manager contacts the railway undertakings whose trains will be affected by this incident. The manager needs to inform the railway undertakings about the incident so that they can decide on what should happen to their respective trains, i.e. if they want their trains to be cancelled or if they should be kept in traffic and rerouted to go around the site of the incident. In the case of the latter, the traffic controller is responsible for planning how to re-route the trains and to execute the plan. While the manager is busy making phone calls to the railway undertakings, Jack gets started on the task of getting railway repairers and a towing train to the site of the incident. A towing train is equipped with a diesel engine and can therefore tow away the train involved in the incident, which otherwise is stranded there as long as the electricity is out. Until the railway repairers have investigated the site and assessed the severity of

**Figure 2.** Screenshot from the traffic control system representing rail (black lines), trains/segment of rail that currently is occupied by a train (red lines), and train paths, which means that a certain part of the rail is dedicated to soon be used by a particular train (green lines). Numbers presented above the lines indicate identification numbers for each train and also numbers for signals and switches.
the breakdown, it is difficult for both railway undertakings and the workers in traffic control to decide on how the situation best should be handled. Therefore, enabling the repairer’s access to the site is a top priority and something that contributes to the traffic controller’s sense of place, which is further developed as he gains more and more information about the site of the incident.

To get the repair work going as soon as possible, Jack contacts the repairers and forwards the information the train driver has provided him with. To access the site of the incident, the repairers have to travel there by train. The Swedish railway system is built in segments of rail and with a safety system ensuring that multiple trains cannot simultaneously operate within the same segment. This is for safety reasons, mainly to avoid collisions. However, this system cannot work when the power is shut down. To still uphold safety for the repairers and the towing train to travel although the rail in this area is officially blocked for traffic, Jack needs to give access to one train at a time and for one segment of rail at a time. Due to the automatic safety system not working with the electricity turned off, the trains are restricted in speed and the controller must ensure via the traffic control system that no other trains are in the area before permitting the railway repairers and the towing train to enter a new segment. This way of work, to repeatedly give access to a train to enter one segment of rail at a time, is time-consuming and requires that the train driver and the traffic controller maintain close contact. While the trains are running and until they reach the next breaking point between segments, Jack focuses on handling the traffic that due to the incident has to be rerouted. Every now and then, he receives phone calls from the repairers and the driver of the towing train as they need permission to enter a new segment of rail. In this way, they are slowly getting closer to the site of the incident. The work process continues like this for several hours to come.

4.2. Handling the incident in the first critical hours

While waiting for the repairers and the towing train to reach their end destination and the site of the incident, Jack attends to the other trains that originally were planned to run in this area at this time period. As mentioned above, his first response to the phone call from the driver involved in the incident was to stop all traffic in the area. This resulted in multiple trains being presented with a stop signal. The trains lined up one after another, and they have now been standing still awaiting further instructions while Jack saw to the top priority aspects of assessing and sensing the breakdown, as described above. Meanwhile, the railway undertakings have been working to decide which trains to reroute and which to cancel and/or replace with road traffic (i.e. buses or taxis). Naturally, the many railway undertakings have distinct priorities given the factors they considered important in this particular situation, such as the number of passengers on board the trains and the distance to their final destinations. Once Jack turns his attention back to the original traffic plan and the long row of awaiting trains, emails are starting to come in, announcing the decisions made by the railway undertakings. At this point in time, the plan is to reroute most of the trains. Due to the location of the incident, this requires a majority of the lined-up trains to go in reverse to exit the affected area and instead travel around it (see Figure 3).

To sort out the situation with trains lining up, Jack attends to one train after another to put the railway undertaking’s decisions into practice. Even the trains that are to be cancelled need his attention since this part of the Swedish railway consists of single-track lines only, meaning that all trains need to get out of the way to free up the rail for the trains that are to be maintained in traffic. Jack works strategically by attending one train at a time. Meanwhile, his traffic controller colleagues are aware of the situation and try to avoid letting trains into Jack’s area since that would only make the number of awaiting trains even higher. To keep track of all the trains, Jack makes use of the identification numbers that are unique for each train and takes notes on a piece of paper. He also uses the key artefacts for traffic control, which are the analogue time-distance graph mostly used for planning and documenting, and the digital traffic control system to set signals and switching points in accordance with his new plan.
The time-distance graph (see Figure 4 for a true example of such a graph, although not the actual one used on the day of the incident) presents an aggregated view of all trains and their original timetables for each traffic control area, which means that they display the location for each train and through time (for more details on the time-distance graph, see Andreasson, Jansson, and Lindblom 2019a). The graph presents the original traffic plan and becomes obsolete in situations like this when the original plan cannot be implemented. However, Jack still makes use of the graph to make sure that he stays on top of the situation, he draws new lines in the graph for the rerouted trains and crosses out trains as they either leave his area or are cancelled, indicating that he no longer needs to keep those in mind. As the graph lists all trains and the geographical positions and stations they will pass throughout their journeys, the graph provides the controller one way to develop an experience of the world outside the control room, thus, helping him develop a sense of place. He also uses the graph to look ahead to make sure that he is aware of all trains entering into his area of traffic control. For each train Jack attends to, he communicates the plan via phone with the train driver. He works as fast as he

Figure 3. This is an abstract drawing of a limited part of the Swedish railway system. The lines represent the railway and the letters A and B mark the two largest cities in this part of the country. The site of the incident is marked with a cross. The green line is the alternative route for the rerouted trains, which is considerably longer and creates a delay of approximately 3 h.
can to clear the line of waiting trains before new ones enter the area. As he continuously sets signals for the trains, he expects the drivers to act as fast as possible so that he can move his attention to the next train in line. On one occasion when a driver was not reacting to the signals as fast as Jack wanted him to, he muttered for himself: ‘What are you still doing there? I told you to hurry.’

The control room for operational train traffic is designed for teamwork with no inner walls separating the workers and right next to Jack sits the information officer responsible for the same geographical area as Jack. While the traffic controller’s responsibility concerns the trains and the flow of traffic, the information officer is responsible for announcing updated traffic information to travellers at train stations and platforms. As Jack is working on rerouting trains past the site of the incident and to give access to the repairers and the towing train, the information officer, George, struggles to keep up with all the information from the railway undertakings concerning the many delayed trains. He, too, focuses on one train at a time and moves through the list of trains that were initially put in a line, awaiting further notice. His main cognitive artefact supporting him in this task is a digital list called the train position image. This list displays all trains that are in the area along with their current location and a number that indicates if the train is following the traffic plan or not. On this particular day, the whole list displays delays and while working, George kept referring to the travellers: ‘I feel so sorry for all these people. It’s a bad day for them.’ Another key artefact for customer information is the information display system which is used to manually update the traffic information that is orally announced at platforms and train stations and visually displayed on information signs installed at these locations.

Figure 4. A time-distance graph with drawings on it to document the adjustments made by the traffic controller. This graph presents a time span of two hours and each diagonal line represents a train and its journey according to the original traffic plan.
4.3. Mitigating the consequences of the incident

At this point in time, approximately three hours have passed since the incident was reported and the repairers have just arrived at the site of the incident. They assess the situation and report back to the control room with an estimation that approximately one kilometre of electrical wire is lying on the ground due to the incident. Their preliminary prognosis is that the repair work should be completed around 10 pm, i.e. approximately 14 h later. In the control room, the workers received the information with scepticism since they felt it was an overly optimistic prognosis and prepared themselves for a long day.

The work in the control room is now focused on continuously handling the incident and its consequences. One especially challenging aspect of this work relates to the fact that when a train is rerouted and changes direction, it is given a new identification number (the numbers should indicate if the train is going north or south – even numbers are used for north going trains while odd numbers are used for the trains going south). These numbers are communicated from the railway undertakings via emails to both Jack and George. They help each other to keep track of all the numbers continuously arriving in multiple emails and both of them take notes to help them remember which numbers are to be replaced. However, while Jack can change a train’s number in the traffic control system and write the new numbers in the time-distance graph and thereon, work solely with the new numbers, George needs to continue using both the original and the new numbers in his work. This is because the numbers displayed at stations and platforms are always the original numbers to avoid confusing the travellers. Therefore, George needs to keep two separate numbers in mind for each train: the new one listed in the internal systems in the control room and the original one used for making announcements to the travellers. To remember all the identification numbers, George makes notes on a piece of paper and draws arrows between the original numbers and the new ones. In the digital train position image system, he keeps track of the new numbers to keep updated on how the trains are running as they continue on their rerouted journey. However, every time he makes announcements to the travellers, he uses the original number. To make matters worse, if the numbers are not manually updated in the internal systems before the trains change their direction, the trains are no longer shown in these systems and both traffic controllers and information officers are blind to what happens to this particular train. This effectively challenges the workers’ sense of place in relation to their understanding of which train is which and what is their current location and creates time pressure and a need to work proactively to keep on top of all trains in the area.

Approximately one hour later (four hours after the incident, i.e. around 9 am), the initial plan, which was to reroute trains, are changed and it is instead decided that the majority of trains should instead be cancelled and the passengers directed to buses replacing the trains. This lowers the workload on Jack as his responsibility ends when the trains are no longer in running traffic. George on the other hand still has a very high workload. He utters ‘When there is a major disruption like this one, and especially when the traffic is cancelled, they [the traffic controllers] have nothing to do while I am swamped.’ As the railway undertakings are arranging replacement buses, George’s work continues as he needs to inform the travellers of the new plan along with details such as when and where they can expect the buses to depart. This means that while Jack can slowly decrease the number of trains that he is responsible for when some, or even most, of them are cancelled, George still needs to attend to all trains whether they are kept in traffic or not. Up to this point, George and Jack work closely together, talking out loud at all times so that they keep updated on what the other is doing, and frequently asking each other questions concerning details in the information they have been given. However, this changes with the decision to primarily cancel trains (instead of rerouting them), making the workload no longer as high for Jack as it is for George. Now Jack sits in silence but is constantly attuned to George’s needs and ready to help whenever possible.
Half-past one in the afternoon (approximately 8 h after the incident), Jack goes off his shift and another traffic controller, let us call her Sarah, takes his place. They do a quick handover as Jack updates Sarah on details she needs to know. Most of the information is scribbled down on the time-distance graph, showing the adjusted routes for each train that has been handled during the morning shift. For a novice, the graph resembles random lines and doodles but for a professional eye such as Sarah’s, it tells her almost everything she needs to know and allows her to get an initial grasp of the situation. Jack informs her that the repairers are still working on fixing the infrastructure and that the towing train has still not arrived at the site of the incident. If Jack had a busy morning, the work situation for Sarah is somewhat different. This is much thanks to Jack who has already straightened out the mess that occurred when the incident first was a fact. When Sarah starts her shift this afternoon, the majority of trains originally planned to run in this area were either cancelled or already planned for being rerouted. She is still, however, attending to the towing train which is slowly getting closer to the site of the incident. George is still facing a high workload and decides to switch places with a colleague who takes over for him so that he can have a break by attending to another area in which the workload is lower. We can call this colleague Anna.

Anna has been working all morning on an adjacent traffic area so she has heard the ongoing conversations between Jack and George and is already up to speed with the situation. The trains lined up from the morning rush have already been taken care of, but there are constantly new trains entering the traffic area and since the repairs are still ongoing, they cannot run through the rail segments from point A to B (see Figure 3 above). Most trains are instead planned to turn around and go back once they reach point A from the south or point B for the trains arriving from the north. When doing so, the passengers onboard the trains and the travellers waiting at the stations need to be informed on how to continue their travels. Anna handles this by actively searching in her email client for updates on each train. In some cases, the information is clearly presented in the emails from the railway undertakings and she makes use of that information to make announcements at the train stations and platforms, informing people where they should go to find the buses that are replacing the cancelled trains. This is, however, not always as straightforward as it sounds. While a train can take hundreds of people, a bus is limited to approximately 50 passengers, which means that each train needs to be replaced by multiple buses. Furthermore, not all travellers are going to the same destination and neither are the buses, which makes it essential for the information officer, Anna, to be abundantly clear which bus is going to which location. Luckily, the logistics of it all, to plan for how many buses are needed and which bus should go where to enable all travellers to reach their planned destination, lies on the railway undertakings to handle. However, there are multiple trains affected and sometimes the information to the control room is lacking. When the emails are not informative enough, or in the case when one train number is left out in the information from the railway undertakings, Anna turns to Sarah to ask for help. As a traffic controller, Sarah has direct access to call the train drivers and does so to ask if they have been informed about the plan forward. If neither Sarah nor the driver of the train is informed about the plan and what will happen to this particular train, Anna needs to improvise. ‘I have not heard anything about 570, no one has heard anything… But all the previous trains from that railway undertaking have been replaced by buses so I guess it applies also to 570.’ She continues: ‘I have to make a decision and get something out there. The travellers are standing there waiting and wondering where to go.’ What further adds to the stressful situation is that the information signs installed at the platforms, the ones that the travellers turn to for information, are based on the clock and programmed to show the original traffic plan. This means that when the expected arrival time for a train has passed, the sign will be automatically updated to show the next train’s planned arrival. This works well unless a train is delayed. Then the information officer needs to move quickly to update the signs before the original time of arrival has passed. Otherwise, the travellers will find themselves presented with information about a completely different train – the next train expected to arrive according to the original traffic plan. The automatic system is not programmed to consider situations when the original plan is obsolete, which creates a time sensitivity requiring that the
information officer is proactive and maintains control over all information regarding all trains that have been affected by the torn down electric wire.

A telling example of the challenges of providing the travellers with accurate and updated information is when Anna receives information about a train that is cancelled and she attempts to guide the travellers to the replacement buses. However, she does not know when the bus will arrive to pick up the travellers at the train station. This means that she cannot give sufficient information and since it is essential that the travellers know when their bus will depart, she engages in an active search for more information. She talks to Sarah whom contacts the train driver. However, neither one of them has heard any details in the planning. Finally, she gets in contact with the bus company and receives the telephone number to reach the driver of this particular bus. She calls him directly to ask for an estimated time of arrival to the location where the travellers are waiting. Once she has accurate information, she makes the necessary announcements to the travellers. ‘It is a good thing that I got a hold of him. Otherwise, I would have had to make a guess … The travellers need to be told something.’ While Anna is searching for the necessary information, she accesses the feed from video surveillance cameras installed at the train station and observes the travellers as they (im)patiently await information about where to go and how to continue their travelling. The real-time video feed supports Anna in her development of a sense of place and enables her to experience and develop a relationship with the location and the people occupying it, with whom she interacts via the information displays.

Both Sarah and Anna are busy with the continuous work to manage the traffic and keep the travellers updated with new information about how their travelling plans are changing due to the incident. The towing train finally arrives at the site around 3 pm and gets started towing the stranded train away. Around 5 pm, the workload was noticeably lower in the control room and it was decided to end the observation session. At this time, there was still no definite time announced for when the traffic could be up and running again but the estimation still said 10 pm. The next day, the newspapers reported on the incident. They stated that more than 25 passenger trains had been severely delayed but that the damage to the infrastructure was now repaired and that the train traffic had been reinstated around midnight.

5. Discussion

With the use of a true case of traffic controllers and information officers involved in Swedish operational train traffic, we have characterised the work practices used for grasping, handling, and making sense of an incident of a torn down electrical wire causing large traffic delays. We have shown how the distributed socio-technical system as a whole has enacted work practices based on acquired experiences and skills that enable it to successfully handle the incident with the overarching goal to mitigate the consequences of the incident, and subsequently getting the trains running again. At the centre of achieving the goal are the human workers who bring flexibility and suitable adaptations and, accordingly, act as invaluable actors who contribute with the capacity to coordinate various resources for the distributed socio-technical system’s possibility to function. Further, it is illustrated how the workers’ reach through time and space, mediated by technology, enables them to develop a sense of place from their first-person perspectives. This sense of place is not merely a result of the work practices as such but something they actively strive to develop and that supports them in handling the numerous situations they face and make sense of in their line of work. In this particular context, we have employed one strand of the conceptualisation of sense of place as the development of so-called ‘centres of meaning’ (Eaton et al. 2019; Raymond, Kyttä, and Stedman 2017; Relph 1976) for certain locations along the rail and the platforms. We have shown that skilled traffic controllers and information officers acquire this ability during their work practices in the control room and by doing so, gain a deeper understanding and meaning of the places ‘out there.’ The control room workers’ experience of being there without being physically present at the site of the incident enables them to carry out sense-making actions. In regard to
this, it is worth noting that although Weick (1988, 1990) has introduced and further developed the sensemaking perspective, we do not fully follow this more cognitively inclined approach to sensemaking (Maitlis and Sonenshein 2010; Sandberg and Tsoukas 2015) and suggest that Weick does not explicitly acknowledge the role and relevance of the contextual dimension in remote work such as elaborated in Relph’s ‘sense of place’ (1976). In this perspective, Relph goes beyond the primarily social construction or representation to emphasise the property of the relationship between the situated actions and the enactment of meaning both within and across place-based experiences (Raymond, Kyttä, and Stedman 2017). In a similar way, practice theories, irrespectively of their theoretical orientation (Kuutti and Bannon 2014), have not paid that much attention to place instead of space, as seen in prior control room work within computer-supported collaborative work (Heath and Luff 1992; Luff et al. 2018; Suchman 1997). During the unfolding of the incident, the traffic controllers in charge used the train driver and the repair workers as their extended ‘eyes and ears’ to develop a sense of place of the occurred incident and its severity. Moreover, the information officers developed their sense of place by making use of the surveillance cameras at the platforms. This enabled them to better grasp the travellers’ information requirements and needs in order to accurately and timely plan and present the passengers’ much-needed information demands.

Relph (1976) points out that a person’s sense of place involves not only physical properties but also activities and meanings and he describe a person’s involvement with a place on a continuum of seven different degrees of outsideness and insideness. This continuum seems to be of relevance for understanding how the professionals that are physically located within the control room are able to move between several places along this outsideness-insideness continuum. In particular, we suggest that the control room workers’ expanded embodied and situated knowledge could be referred to as what Relph (1976) called ‘vicarious insideness,’ which refers to a secondhand way of experiencing a place without being physically situated at that place, but still being involved with the place. We propose that the transportation between the physical location of the incident and the platforms as being the experienced place is partly mediated by the technology (cf. e.g. Hollan, Hutchins, and Kirsh 2000; Hutchins 1995; Luff et al. 2018) or by others who are first-hand situated at the location: in this case, particularly the train driver and repair workers. Another of Relph’s concepts is the ‘incidental outsideness’ (Relph 1976) which refers to a place that is experienced as an incidental background for activities, meaning that what the person is doing overshadows where the person is. This offers a compelling insight for contextualising the experiences of the remote work practices that occur in the train traffic control room since the experience is enacted by the professionals when they need to act upon a situation that takes place at another location. We therefore propose that the incidental outsideness is a kind of place experience since the activity itself is the focal point of attention in which the workers are acting upon what they perceive from within the control room, moving beyond the typical dimensions of time and space. By shifting the focus from ‘space’ to ‘sense of place,’ our intention is to provide additional insights by shedding light on how human adaptability contributes to the successful handling of the incident.

This paper contributes to the rather scarce research on work practices in operational train traffic in railway research, in which a systems perspective has been called for (e.g. Andreasson, Jansson, and Lindblom 2019b; Wilson and Norris 2006). We have also contributed to the study of the human contribution as the glue that makes safety-critical systems, such as operational train traffic, perform via acquired work practices. As pointed out by Lebahn-Hadidi et al. (2023) most reports on incident handling usually stress what should have been done rather than what actually was done (Hollnagel, Wears, and Braithwaite 2015; SHK 2017). In relation to this, there is an ongoing shift within safety research about the role of the human worker, from viewing the human as a risk factor that has to be handled to viewing the human as a flexible resource who contributes to the socio-technical system’s performance (Dekker 2015; Hollnagel, Wears, and Braithwaite 2015; Leveson 2020). These perspectives are referred to as Safety I, Safety II, and Safety III/Systems Safety (e.g. Hollnagel, Wears, and Braithwaite 2015; Leveson 2020). Briefly stated, in the traditional Safety I approach, the focus is on the individual human and there is often negative connotation when an incident
occurs. It is a reactive approach that concentrates on ‘what goes wrong,’ perceiving humans as potential risk factors and a source of errors. However, the new approach of realising and developing safety, Safety II, focuses on what goes well, highlighting success factors that maintain safety. In this approach, the humans are perceived as assets who contribute with flexibility and are able to mitigate consequences and make sure that the work is done despite unpredictable conditions (Hollnagel, Wears, and Braithwaite 2015). Safety III expands upon Safety II and focuses on the whole socio-technical system and the inclusion of safety in the design of the technical parts. Leveson (2020) argues that the whole system has to be designed to allow human workers to act flexible and resilient in order to handle and cope with unexpected situations. It is our intention to portray how the professional workers in the train traffic control room successfully made sense of a critical situation, like the above incident with the torn-down electrical wire, and we hope to provide the deserved attention of successful work practices as explicitly asked for by Dekker (2015).

5.1. Limitations and future work

This paper reports on a type of incident many of us have heard of but few have had the opportunity to investigate and analyse as they unfold in situ; a result of the unpredictable nature of situations like this one. Neither photographs, audio nor video recordings were allowed due to strict security regulations, which created restraints on our analysis, especially in regards to the exact chronological order and the ‘temporal bracketing’ strategy of how the incident unfolded itself, and also in relation to the depth and level of details in the analysis (Langley 1999). Further limitations relate to the report being based on a single case and we are fully aware of the limitations in this. We do not, however, aim to generalise from this sample to the full picture of accidents and incidents handled in operational train traffic. However, as Gerring (2007, 1) argues, ‘Sometimes, in-depth knowledge of an individual example is more helpful than fleeting knowledge about a larger number of examples.’ The work reported here seeks to gain a better understanding of work in operational train traffic by studying this case in depth rather than by generalising across multiple cases.

In future work, we hope to continue to explore how and to what extent the ‘sense of place’ concept can be applied to aid a deepened understanding of the work practices in operational train traffic. The challenges of this domain are similar to those of other complex domains, especially in the transportation sector, and we aim to further investigate how this concept can provide insights into how work gets done in such domains. Relph (1976) presents an interesting and viable approach to handling the distributed and broadened unit of analysis beyond being physically situated in the control room. We are especially interested in further explorations of his idea of the insideness and outsideness continuum (Relph 1976) to add further dimensions to the ‘sense of place’ concept as used in this paper. We find his characterisation of insideness and outsideness as complementary reflections of the nature of one’s involvement with a certain place that includes physical properties, activities, and meanings. Relph’s original work has been further developed to encompass that activities and meanings are being mediated by various forms of technology. This makes it possible to a certain extent to reproduce a surrogate experience of being physically situated at a place, implying several degrees of insideness and outsideness for the experience of ‘being there’ (Tjøstheim 2020). In light of the rapid technological development changing how we live and work, we find it interesting that there is an ongoing discussion about to what extent theory development follows the current challenges involved in studying work practices. We foresee that collaborative workers will be even more separated in time and space, which has implications for the usage and further development of the ‘sense of place’ concept for both digital and physical work experiences. We emphasise that the ongoing technical development calls for a theoretical development of current concepts, raising questions of how new technologies affect current meaning making approaches of human–environment relationships.

Moreover, beyond the theoretical considerations, we also encounter additional methodological challenges. The distributed nature of work in operational train traffic, reaching through time and
space both within and outside the control rooms, make it physically impossible for the researchers to observe the complete chronological development of the situation and work practices described and analysed. This challenged the analysis and our possibility to understand all nuances of how the incident unfolded, was handled and experienced by all involved parties both on-site and remotely. This is an outcome of the complex nature of real-life happenings, which is the focal point of ethnographic and workplace studies, but it can result in limitations in data collection and analysis (see Luff et al. (2018) for similar lines of argument). Besides this, for future research we may also need to apply methods that more appropriately capture central dimensions of the sense of place concept. Examples of such methods could be phenomenological ethnography which has been used to elicit how experts enact various diagnoses in a healthcare setting by focusing on the workers experiences and meaning at work (Briedis 2020).

5.2. Concluding remarks

By shifting the focus from ‘space’ to ‘sense of place,’ our intention is to provide additional insights by shedding light on how human adaptability contributes within these complex and distributed socio-technical systems, showing how it is accomplished in practice as well as gain some more clues on what may constitute successful work under unexpected circumstances. We hope that our reporting in this particular handling of the incident is aligned with Leveson’s (2020) safety systems view of a socio-technical system. She points out the problematic stance when the focus is primarily only on the human operators and “human error,” or even on only the technical components, then we have too small a keyhole to allow us to understand and solve our problems, including improving safety. The impact of the technical design and the social systems on each other, i.e. the integrated sociotechnical system behaviour, must be considered to deal with safety in our complex world today. (Leveson 2020, 43)

To conclude, we argue that this kind of studies are much needed since research on human adaptability within the web of distributed and complex socio-technical systems currently is, and has been for a while, a rather neglected research area in human-technology interaction. Although the focus on technological progress in automation and artificial intelligence is plentiful and conducted across domains, humans are still essential within these webs of distributed and safety-critical socio-technical systems in order to get the work successfully done.

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