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Information-based Disturbance Management for Public Transport

Project report 1

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Innehållsförteckning

Preface

This report reflects the main results from phase I and parts of phase II, of the project "Disturbance management and information availability in public transport". The following activities are covered (taken from the project plan):

1. Identifying a set of the most relevant disturbance scenarios. The idea is to focus on scenarios that truly affect commuters and that hold potentials for actions which can actually support the commuters
2. Identifying current practice as well as potential actions (re-planning) in case of relevant disturbance scenarios. The idea is to include potential actions which may today not be used due to, for instance, lack of information and lack of information communication channels to relevant actors (including travelers).
3. Identifying the information needs by different actors (including traveler) connected to the different scenarios and potential actions. The traveler's information needs, mainly concern relevant information to support the traveler to take actions (i.e. re-plan the journey, or avoid unnecessary actions). An important aspect is the understandability for the traveler. (*Characterization of the information in terms of accuracy and reliability has not been performed*.)
4. Identifying the availability of information (connected to the needs above) including the source (e.g. organization and information system holding the information); and processing needs for the different scenarios and actions. Also aspects of problems (or unwillingness) to make the information available will be investigated. (*Aspects of accuracy and reliability have not been considered*.)
5. Information gap analysis from a system perspective (including relevant actors and scenarios), including:
    a. Mapping of the information needs with the information availability (by the different scenarios, actions and actors) considering users of the information, and sources. (*Aspects of accuracy and reliability have not been considered*.)
    b. -
    c. Identify potential system improvements given the mapping above (e.g. need of new source, shifted responsibility of information maintenance, and data processing).

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Summary

The environmental problems currently faced worldwide have raised awareness of different transport alternatives and their consequences. In particular, public transport systems are often seen as important means to increase sustainability. However, public transport systems must be both reliable and accessible, in order for people to select public transport over private car usage, which is not always the case. Based on interviews with the actors involved, literature review and analysis, this report investigates the missing information and communication flows, in the public transport system of southern Sweden. Both the perspectives of the actors and the travelers are in focus. Based on this investigation, a number of potential solution approaches are presented and discussed. In particular, an information system common for all public transport actors in the region, and a traveler check-in system are proposed. The common information system would enable more efficient information sharing, and the traveler check-in system would enable better traveler information and services.

1. Translated concepts and abbreviations

English denomination	Swedish denomination	Abbrev.	Organisation (in this report)
Dispatcher	Trafikledare		Trafikverket
Information Officer	Informatör		Trafikverket
National Operative Management	Nationell Operativ Ledning	NOL	Trafikverket
Operations Technician	Drifttekniker		Trafikverket
Operative Leader	Operativ Ledare	OL	Trafikverket
Operative Management Meeting	Operativt Ledningsmöte	OPL	Trafikverket
Operative Management System	Operativt Ledningssystem	OLS	Trafikverket
Regional Operative Management	Regional Operativ Ledning	ROL	Trafikverket
Technical Operations Leader	Driftledare	DL	Trafikverket
Traffic Center	Trafikcentral	TC	Trafikverket
Traffic Information Center	Trafikinformationscentral	TIC	Skånetrafiken
Traffic Information Leader	Trafikinformationsledare	TIL	Trafikverket
Traffic Information Team	Trafikinformationsstab	TIS	Headed by Trafikverket, several included
Traffic Management Area South	Trafikledningsområde Syd	TLO Syd	Trafikverket
Traffic Management Interaction	Trafikledningssamverkan	TLS	Developed by Samtrafiken, several have access
Train Driver	Tågförare		Train operator
Train Leader	Tågledare	TL	Trafikverket

2. Referred public transport actors

This report refers to the following public transport actors:

- *Arriva* is a subsidiary of the German railway company Deutsche Bahn. In Sweden, Arriva is currently the train operator responsible for Pågatågen, providing regional rail services in the south of Sweden (primarily in the Scania County). Skånetrafiken acts as the ordering party towards Arriva. In case of disturbances, Arriva may take passengers from other train operators. In this report, we call this a train replacement train operator. In relation to the scenarios described in section 5, Pågatågen trains are running between Lund and Malmö, and between Helsingborg and Malmö. It is also possible to travel half way to Växjö from Malmö, with Pågatågen.
- *Nobina Sverige AB* is a bus operator who is currently responsible for city bus traffic in several cities within the Scania County in Sweden, e.g. Malmö and Helsingborg. Nobina also currently operates regional bus traffic in the western parts of Scania, e.g. between Lund and Malmö. Skånetrafiken acts as the ordering party towards Nobina. In the northern parts of Scania, Nobina may be hired for replacing trains, in case of rail disturbances. In this report, we call this a train replacement bus operator.
- *Samtrafiken* is a service development company owned by nearly 40 different traffic actors, each with equal percentage of ownership (Samtrafiken 2013). Samtrafiken acts as an independent party where common challenges are discussed and met with collaborative solutions. The goal is to make public transport simpler, more available and more reliable. Samtrafiken develops services for both traffic companies and travelers.
- *SJ AB* is a rail operator owned by the Swedish government, and operating under market conditions and requirements. SJ trains are running all over Sweden. In the southern parts, SJ operates primarily intercity and high-speed trains. In relation to the scenarios described in section 5, it is possible to travel by SJ between Malmö and Helsingborg, and between Växjö and Kastrup, but not between Malmö and Lund.
- *Skånetrafiken* is an administration within the County Council of Scania County in Sweden, which is responsible for the public transport in the Scania County (Skånetrafiken 2016). Skånetrafiken plans, procures, informs about, markets and sells the traffic, based on directions from the County Council. Skånetrafiken has the overall responsibility for bus and rail traffic, as well as transportation services for people with special needs. Skånetrafiken has a Traffic Information Center ("Trafikinformationscentral", *TIC*), which is responsible for communications with the transport operators and Trafikverket, as well as for delivering traffic information to the travelers. The TIC is represented at the TCs (see below).
- *Trafikverket* (the *Swedish Transport Administration*) is a Swedish administrative authority responsible for the overall long-term infrastructure planning of road, rail, sea and air transport (Trafikverket 2015a). It is also responsible for the construction, operation and maintenance of state roads and railways. Within Trafikverket, the National Operative Management ("Nationell Operativ Ledning", *NOL*) has the overall traffic coordination responsibility (primarily concerning traffic management and traffic information) from a national perspective (Krasemann 2014). The NOL prepares the operative work together with four Regional Operative Managements ("Regional Operativ Ledning", *ROL*). The ROLs are each responsible for one traffic management area. These four areas contain eight Traffic Centers ("Trafikcentral", *TC*) in total, which together monitor and control the main part of the Swedish rail traffic. In addition to these TCs, around 70 local production places manages specific local rail sections. In general, Trafikverket is mostly concerned with different traffic links, not a traveler's whole journey from origin to destination, which may include several line changes. Skånetrafiken and Samtrafiken are more concerned with the latter.

- *Transdev i*s a transport company currently responsible for providing regional rail services in the Öresund region, together with a Danish operator DSB Øresund. Transdev operates the Swedish side and DSB Øresund operates the Danish side. The common rail traffic network is called Öresundståg. In particular, Öresundståg trains are running on all lines specified by the scenarios.

3. Introduction

The environmental problems currently faced worldwide have raised awareness of different transport alternatives and their consequences. In particular, public transport systems are becoming increasingly popular. In Sweden, this growing interest is reflected by an increase of regional and local travels using public transports, with 28% from 2004 to 2014 (Trafikanalys 2015). Substituting car usage with public transport has several advantages, such as, decreased emissions, congestion, and road wear. However, public transport systems must be both reliable and accessible, in order for people to choose them over the private car. Unfortunately, this is not always the case. For instance, trains are sometimes delayed or even completely cancelled due to unexpected events, such as, track intrusions/medical emergencies (e.g. railway crossing incidents), weather extremes, or track/rolling stock failures (Pender et al. 2012). Obviously these types of deviations from timetables usually affect the travelers using or intending to use public transports. In addition to the actual delay to the intended destination, different types of discomforts may also arise, e.g. uncertainty about arrival time and uncomfortable waiting time or waiting locations. We believe that by making public transport more efficient and reliable, a number of positive effects related to sustainability can be achieved. For instance, more travelers may be encouraged to choose public transport instead of private cars, personal time wasted on travelling can be reduced, less resources (e.g. extra busses) may be needed, and discomforts in travel can be decreased.

Naturally, there is a high level of dependency between transport operations within each transport mode, but also between operations in different modes of transport. Disruptions are thereby likely to spread over one or several transport networks in space and time – a phenomenon which is called the knock-on effect (Jespersen-Groth et al. 2009). During peak hours, when the amount of commuters is high and traffic is condensed, this problem is further magnified. In order to mitigate these effects, close cooperation and coordination between all actors involved, is needed. Deregulations within public transport have increased the number of actors, and thereby also the number of decision levels and IT-systems. This has made the cooperation and coordination in public transport systems even more challenging (O'Sullivan & Patel 2004; Sørensen & Longva 2011). In situations of disturbances, both travelers and actors therefore have problems in getting an accurate view of the situation, including available options for immediate action. For instance, inefficient information sharing often causes poor awareness between the actors of each other's planned and ongoing actions. In order to improve this situation, the Swedish Transport Administration is actively working for increased co-modality and coordination between different actors in the public transport systems (Trafikverket 2014a). In particular, it is important that each mode of transport performs well in terms of availability and reliability, both individually and in cooperation with each other (Trafikverket 2014a). Even though some efforts are made to generate reasonable connections between transport systems operated by different actors (either within the same or different modes of transport), inconveniences still occur for the travelers, for instance when traffic is delayed or when they are buying tickets.

In itself disturbance management is a complex problem due to the many interconnections and dependencies (e.g., the actions of one actor influence the other actors) as well as the significant influence of uncertainties (e.g., concerning how long will it take to repair a vehicle). The issues of timetable readjustment, and rolling stock or crew rescheduling, including decision support methods from the operator perspective, seem to be rather quite well studied, particularly when considering only one mode of transport (see, for instance (Törnquist 2006; Nikolić et al. 2015)). The work in readjustment and rescheduling usually aim to restore feasibility and move stranded commuters as fast as possible through the system, most often based on the perspective of the transport operator (Darmanin et al. 2010). Jespersen-Groth et al. (2009) describe and discuss these problems, as well as gives an overview of the existing literature. However, studies addressing the negative effects of delays from the perspective of the travelers, appear to be relatively more sparse, though they do exist. As an example, Binder et al. (2015) introduce a hybrid methodology for timetable recovery that takes the satisfaction of both travelers and railway companies into account. Their aim is to minimize the overall passenger disutility as well as operational costs. Darmanin et al. (2010) experiment on diverting existing route buses and let them cycle between two adjacent railway stations, between which there is a disruption, before returning to their normal routes. As a result, the response time is reduced in comparison to hiring charter buses from a bus depot, and the uncertainty related the number of buses currently available, is removed. Finally, Zeng et al. (2012) explore how taxis can be used as a resource during short-term disruptions in public tram systems. In particular, they study the decision of ordering taxis by finding a balance between passenger service level and costs.

As for information in particular, from the perspectives of travelers, some researchers have focused on information needs (Zografos et al. 2010; Grotenhuis et al. 2007), the behavior of travelers in relation to the information available, and the requirements of the next generation travel planners (Skoglund 2014; Kramers 2014; Chorus et al. 2007). In particular, Grotenhuis et al. (2007) show that real-time information on delays and route advice to avoid delays, are highly desired by travelers. The value of real-time information during travel is confirmed by other studies (Skoglund 2014; Robinson et al. 2012), and some show that travelers require the information to be accessible from a variety of sources (Robinson et al. 2012; Bachok 2007). Cano-Viktorsson (2014) also focuses on the real time aspects of information exchange, including the perspective of the operator. Crowdsourcing is sometimes used for improving real-time information and planning (Zimmerman 2011; Seltzer 2013). For instance, travelers might contribute with information into a service system by generating real-time information about bus seat occupancy rate, or bus arrival time using their GPS-enabled mobile phone (Zimmerman et al. 2011). Quality control of crowdsourcing applications is, however, an important issue since there might be problems with the credibility of the data provided by travelers (Mashhadi & Capra 2011).

In summary, the current approaches typically focus on one operator's view of problems, without putting much effort on the information and communication needs from the aspects of multiple actors (e.g. information fusion requirements). Furthermore, the potential advantages of collecting real-time information from travelers is relatively unexploited.

The overall aim of this study is to identify information needs and potential solutions concerning the information flow between actors and to/from the traveler, in order to facilitate appropriate replanning during unplanned disturbances, both for the actors and the travelers. Improved solutions would, in turn, increase availability and reliability of public transport, and thereby hopefully encourage more people to choose public transport over private car usage, with an increased sustainability as a result.

More specifically, we have studied information availability, information needs and other information-related concerns, related to disturbance management in transport systems. Our ambition has been to interview all types of public transport actors that may be involved in, or affected by, a regional rail traffic disturbance in the southern part of Sweden. Actors operating different modes of transport that may serve as alternatives during disturbances, have also been included. Additionally, we have collected information from a workshop focusing on increased collaboration during public transport disturbances, in Sweden. Based on the information collected from the interviews and the workshop, a number of information-related problems have been identified, both from the perspective of the actors and of the travelers (commuters are in focus). The problems have in turn been analyzed in order to distinguish the current information gap (between the current situation and the needs). Based on the information gap analysis, we elaborate on different solutions for overcoming the gap. In particular, solutions based on Information and Communication Technology (ICT) are considered.

In Sweden, a new law concerning the rights of public transport travelers, came into force on April 1, 2016 (Sveriges Riksdag 2015). Since the law affects the transport operators' responsibilities to the traveler in case of disturbances, in terms of information provision and compensations/prize reductions, we have included the estimated effects of the law in our studies as well.

The remainder of this document is structured as follows. Section 4 describes the research methodology and process. In section 5, a number of disturbance scenarios are presented, that have been identified as highly relevant in terms of effects on commuters and potentials for actions to support the commuters. These scenarios have enabled focus on the most relevant aspects. Based on the results from the interviews and other information sources, section 6 describes the information currently available, including the information flows within and between different public transport actors, during unplanned disturbances. Thereafter, the identified problems and the effects of the new law, which are used to distinguish missing information and communication processes, are all presented in section 7. In section 8, potential solution approaches are introduced and discussed. The results are concluded and discussed in section 9. Section 10 describes other related projects.

4. Methodology

We have conducted interviews with all types of public transport actors that may be involved in, or affected by, an unplanned regional rail traffic disturbance in the southern part of Sweden (Scania County). In particular, we have focused on the scenarios described in section 5, during these interviews. The aim of the interviews was twofold; firstly to understand how unplanned disturbances are managed today and how information flows within and between different transport actors, and secondly, to identify information-related problems and improvement potentials with current systems. The interviews conducted were semi-structured expert interviews, and the underlying questions can be found in the appendix.

The interviewed public transport actors were:

- Trafikverket
- Skånetrafiken
- Arriva
- Nobina
- A taxi company, who operates in the Scania County

After each interview, we have summarized the current situation and the identified problems, as interpreted from the interview, and sent this text to the interviewee for comments. Most often the interviewee has verified the content directly. In some situations, though, the interviewee has had some comments on the text. The text has then been corrected according to the comments, and sent back to the interviewee. In all these cases, the interviewee has hereafter verified the content as being correct. The interviewees have also verified that no significant information from the interview has gone missing.

In addition to the interviews, we have participated in a workshop focused on collaboration during public transport disturbances in Sweden (organized by Samtrafiken in spring 2016 (Samtrafiken 2016). The workshop had 60 participants, ranging from train drivers and administrators to CEOs. It was divided into a number of group discussions, and the results from these discussions were registered in a software application, by the discussion group leaders themselves (while supervised by the other group participants). From this application, we have retrieved all information-related problems and improvement potentials, identified in the discussions.

Finally, information has been collected from different types of documents and research literature (see reference list). We have also visited the TC in Malmö to get an understanding of how things work there during disturbances.

The summaries of the interviews formed a map over the current information flows within and between different public transport actors, during unplanned disturbances. This map played an important role for the subsequent research steps, since it helped to create an understanding of the current transport systems. As mentioned above, the interviews were also used for identifying problems and improvement potentials, including things that are not possible today but is requested by the interviewees. The information from the workshop was also added to this list of problems and potentials. Thereafter, the new law concerning the rights of the public transport travelers, was studied and analyzed. The results from this analysis was used, together with the list of problems and potentials, to identify missing information or communication processes. Finally, based on analysis, literature studies, and ideas from the interviewees and the work shop, we developed a number of potential solutions for collecting the missing information and introducing the missing communication processes.

The main steps in this research process is illustrated in Figure 1.

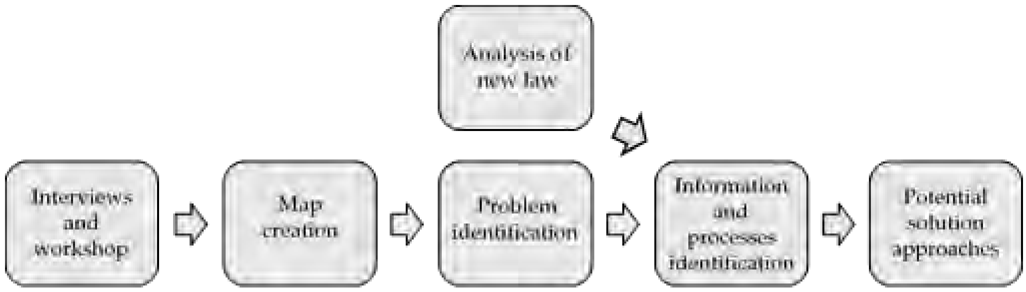

Figure 1 Main steps in the research process

5. Scenarios

The project has decided to focus on the following scenarios:

Complete stop in rail traffic between Åkarp and Lund, thus affecting the traffic between Lund and Malmö. The stop occurs during busy hour. The prognosis says the stop will last for around:

- 20 minutes
- 60 minutes
- 3 hours

The following traveler types are of particular interests:

- Commuter travelling from Lund to Malmö, by Skånetrafiken
- Commuter travelling from Helsingborg to Malmö, by Skånetrafiken
- Business traveler going from Växjö to Katrup, for onward travel by air from Kastrup

One of the reasons for selecting these scenarios is that they allow for different actions to mitigate the disturbance, both for the transport actors and the passengers. For instance, the rail traffic may be redirected to other tracks through Kävlinge and Lomma. However, the accessibility of these tracks is limited since they are single tracks. Furthermore, there is a regular bus line between Lund and Malmö. This line does not travel directly from Lund station to Malmö station, though. Additionally, the distance between Lund and Malmö is relatively short, which means that some of the commuters might be able to use private alternatives, such as going by car, by bike or taking a taxi.

Another reason for selecting these scenarios is that the stretch of track between Lund and Malmö is heavily loaded, with limited opportunities for recovery (Trafikverket 2014b, 2015b, 2015c). For instance, a delayed train affects other trains if the train is more than 5 minutes late from Copenhagen or from Lund during peak hours, and if it is more than 10 minutes late outside peak hours (Trafikverket 2014b, 2015b, 2015c). The stretch is furthermore involved in several different train-lines (managed by e.g. Pågatågen, Öresundståg, SJ), and a lot of freight also travel on these tracks. This means that disturbances between Lund and Malmö often have severe implications for several travelers within public transport, as well as actors within the supply chain. Moreover, many different origin and destination pairs are affected.

The findings in this report are not limited to the above scenarios but they have been used for fostering the discussions, by concretizing different types of disturbances.

6. Current information availability

6.1. Disturbance plans

The actors involved in and affected by train disturbances have commonly agreed on a number of disturbance plans. For the south of Sweden, the actors in question are typically: Trafikverket, Skånetrafiken, Arriva, Transdev, SJ AB, DSB, Green Cargo, CargoNet, DB Schenker, EuroMaint Rail, TraffiCare and Branchföreningen Tågoperatörerna. The disturbance plans primarily describe what rail traffic changes should be implemented, in response to different types of disturbances. The disturbance plans for Malmö-Copenhagen, Malmö-Hässleholm and Lund-Ängelholm state that they should be activated whenever a disturbance is predicted to last for longer than 10 minutes, but shorter than 6-8 hours (Trafikverket 2015b, 2015c; Trafikverket 2014b). In the south of Sweden, the ROL at the southern traffic management area ("trafikledningsområde Syd", TLO Syd) decides whether a disturbance is such that the disturbance plans should be activated (Trafikverket 2015c). In case the disturbance involves a connection between Denmark and Sweden, the Danish counterpart may also take the decision to activate the disturbance plans.

The disturbance plans for Malmö-Copenhagen, Malmö-Hässleholm and Lund-Ängelholm are based on the following general principles (amongst others):

- Disturbed traffic shall as far as possible not affect undisturbed traffic.
- Trains with larger passenger volumes shall be given priority over trains with smaller volumes.
- Through trains to/from Sweden are prioritized
- The rail traffic should solve their own problems as far as possible, i.e. train replacement buses should be avoided if possible.

The disturbance plans are divided into three different levels:

- **Level A – Delays**
  These disturbance plans are used in situations where there has been a delay but the capacity of the infrastructure has not been reduced.
- **Level B – Reduced capacity**
  These disturbance plans are used during acute infrastructure disturbances when all traffic cannot be run according to the regular time table. Typically, reduced capacity implies single-track capabilities for a stretch of tracks.
- **Level C – Complete stop**
  These disturbance plans are used during acute infrastructure disturbances when no traffic can run on a stretch of tracks or within an area.

During delays, the following basic conditions generally apply:

- Timely trains have priority over delayed trains and trains which run too early in relation to the time table
- The train operator may prioritize within their own assigned time schedule.

The disturbance plans are updated when there is a larger need, and at least once a year when the train plans are changed.

6.2. Open data

Both Samtrafiken and Trafikverket offer open access to traffic information, via APIs (Application Programming Interfaces). Samtrafiken's APIs can be reached via Trafiklab (www.trafiklab.se) whereas Trafikverket's APIs are reached via Trafikverket's home page (api.trafikinfo.trafikverket.se). Both APIs provide information about time tables and the trains' actual arrival/departure times to/from the train stations (at least for Skånetrafiken). Trafikverket's APIs furthermore allow access to information about estimated times of arrival/departure, train messages (for instance about works on the tracks or broken trains), and deviations (for instance concerning train replacement buses or track changes).

6.3. Information flow during train disturbances

The content of this section has been verified by the information providers, i.e. Trafikverket, Arriva and Nobina.

Figure 2 illustrates the information flow between the public transport actors, as well as to the traveler, during unplanned disturbances.

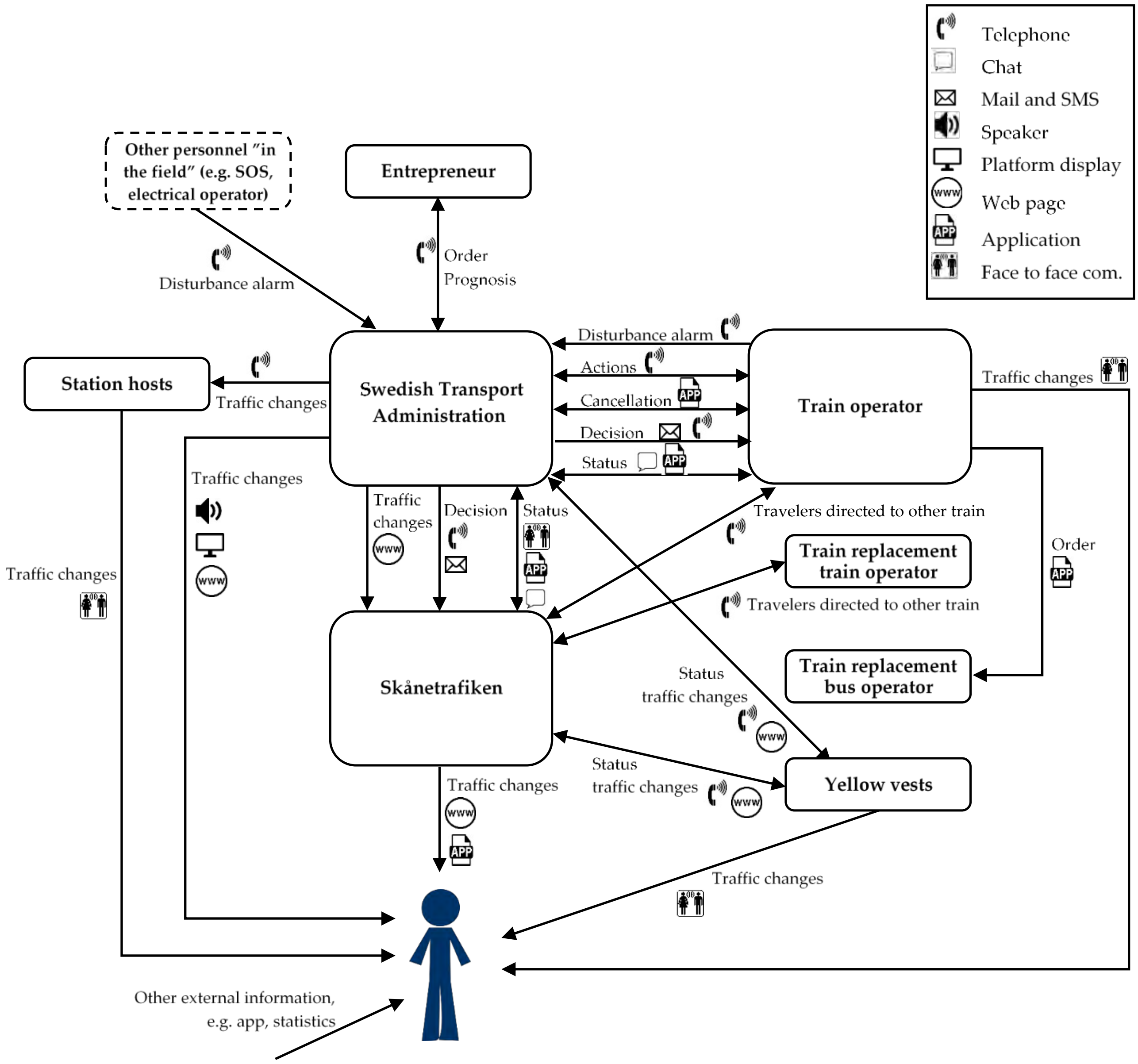

Figure 2 Information flow between actors and to the traveler during disturbances

The disturbance management process almost always starts with a phone call. For instance, a train driver (train drivers have communication channels to both Trafikverket and the train operator) or an electrical operator might call a dispatcher to alarm about some disturbance, such as an obstacle or people on the tracks, a missing train driver, or a fallen electrical wire. As for fallen wires, the TC personnel in Malmö are also able to discover those through their displays; however, they do not have continuous supervision of this.

If the implications of a disturbance are minor, and for instance affect only one train operator, all necessary subsequent communication is handled via telephone. If the disturbance is feared to affect several trains, for instance, if the tracks are blocked or there is a relatively large delay for some other reason, information about the disturbance is orally communicated to the TIC representative at the TC and the ROL. The ROL consists of the following group of people:

- Traffic Information Leader ("Trafikinformationsledare", *TIL*): head of the Information Officers ("Informatör")
- Train Leader ("Tågledare", *TL*): head of the Dispatchers ("Trafikledare")
- Technical Operations Leader ("Driftledare"): head of the Operations Technicians ("Drifttekniker")
- Operative Leader ("Operativ Ledare", *OL*): head of TIL, TL and the Technical Operations Leader

Within 5 minutes after the start of the disturbance, the ROL holds an Operative Management Meeting ("Operativt Ledningsmöte", *OPL*), where the TIL, the TL and the technical operations leaders present the facts and status of the disturbance, as well as suggest possible actions. Ultimately, it is the OL who is responsible for taking decisions about what to do and which disturbance plans to apply. New OPL meetings are held whenever new information is available regarding the disturbance.

More severe implications, furthermore, call for a Traffic Information Team meeting ("TrafikInfoStab", *TIS*), which is held with all railway actors involved (i.e. entrepreneurs and bus operators are not present), approx. 15 minutes after the alarm. Thereafter, new TIS meetings are held at regular intervals, or when needed, until the disturbance has lifted.

Before the first TIS meeting, a number of tasks must be performed. A chat for status information is initiated by the TIL, involving internal personnel, as well as all relevant Swedish and Danish traffic actors, such as Skånetrafiken, Arriva, SJ, Transdev, and the Danish TIL counterpart. The TIL also writes a message for the media, contacts the radio and sends an invitation via email to the railway actors concerning the forthcoming TIS meeting. Furthermore, whoever is closest to the disturbance event (e.g. the information officer, the train leader or the dispatcher), creates an event in a system called Basun. The information officers then adds an information plan to this event, e.g. concerning which delay to communicate to the travelers. The information written in Basun appears on Trafikverket's web page. Moreover, the information officers also use a system called Anno, to communicate disturbance-related information to the travelers, via the platform monitors. They furthermore specify the platform announcements, which are called out by an automatic announcement system called Järda. Since the information officers may not have full information about the disturbance and its implications yet, they base their predictions, to some extent, on experience. During all these activities, the technical operations leader and the operations technicians keep close contact with the entrepreneurs, to get a reliable prognosis as soon as possible. In total, they are in contact via telephone with the entrepreneur at least four times: initially, when entrepreneur gives an estimation of the time of arrival to the place of disturbance, when someone has reached the place of disturbance and the troubleshooting starts, when the work to solve the problem starts, and finally, when the work has finished. Normally, all these calls are not done in time for the first TIS meeting.

The TIS meeting takes place over the phone. During this meeting, Trafikverket informs the actors of which disturbance plan they have decided to apply, and specific questions related to this are discussed.

The discussions may, for instance, concern the prognosis, what to do with stalled trains, whether certain individual trains should be allowed to pass regardless of what is written in the disturbance plans, or whether certain trains should be cancelled to lighten the traffic (in addition to the cancellations prescribed by the disturbance plans). The decided disturbance plans are also communicated to the railway actors via email. At the TIS meeting, they furthermore decide whether so called yellow vests or train replacement buses are needed, or if travelers should be directed to other trains. Yellow vests are train personnel (primarily onboard and administrative personnel) who put on yellow vests and give face-to-face disturbance information to travelers at the train stations, during more severe disturbances. The yellow vests receive updated information from the TIC and Trafikverket via an intranet and via telephone.

The affected train operator is responsible for ordering train replacement buses, which replace trains and drive the passengers to the train stations, instead of the regular trains. The train replacement buses are often tourist buses, which sometimes are driven by chauffeurs with limited knowledge of the local roads. Furthermore, it often takes up to an hour (sometimes even longer) for these buses to reach the point of departure. The train operators order train replacement buses from a common train replacement bus operator, via an application. The train replacement bus operator applied by SJ, Öresundståg and Skånetrafiken is a company called Bussakuten, which is owned by Transdev. Öresundståg and SJ both have their own contracts with Bussakuten, whereas Arriva does not. Instead, the agreement on train replacement bus traffic is concluded between Skånetrafiken and Bussakuten. This means that Arriva is responsible for ordering the buses, whereas Skånetrafiken is responsible for paying the bus operator. There are plans, however, to transfer the agreement to Arriva in the future. Since all train replacement buses are ordered via Bussakuten, they might run out of available buses. A further complicating factor is that there are often more than one train operator between different affected stations, implying that the different train operators may assess the situation differently. There is no common agreement on bus sharing between the operators, which means that some buses might be driven relatively empty back and forth while travelers from the other train operators are left behind (if there is a relatively large imbalance between the amount of travelers from the different train operators).

Directing travelers to trains controlled by other operators is possible thanks to an agreement between Skånetrafiken and SJ. This agreement allows SJ travelers to ride with Öresundståg or Pågatågen on certain routes during disturbances, and vice versa, assuming prior notification has been made (Trafikverket 2015c).

In addition to the information flow related to the TIS meeting described above, a new traffic management interaction system has been developed by Samtrafiken. The system is called *TLS* ("Trafiksamverkan") and allows for relatively informal chat communications between different actors. Additionally, it shows the positions of the GPS-equipped trains in real time, and whether train replacement buses have been ordered. In the Scania County, this system is mainly used by Skånetrafiken for communications with the train operators. As for information about traffic changes, Skånetrafiken continuously collects updated information from Trafikverket's web page.

A train operator might request a train to wait at a train station until another, delayed train arrives, if some of the onboard passengers are supposed to change between the two trains at that station. Thereby, further delays for the passengers may be prevented. Before a decision about waiting for another train is made, the affected train operator first asks Trafikverket about the consequences of waiting. It is then up to the affected train operator to decide whether to wait or not.

The traveler gets information about the disturbance from a number of sources. As mentioned above, Trafikverket informs the traveler via the announcement system, platform displays and their web page. Both SJ and Skånetrafiken informs the traveler via their travel planners and web pages. However, the travel planners have no replanning capabilities in case of disturbances, they only show the updated time tables. Onboard train personnel receives information about traffic changes from their employer, i.e. the train operator, and informs to the onboard travelers face to face. The information to the onboard personnel is received either electronically (e.g. Arriva primarily sends information via email) or via telephone. Some stations have local station hosts, who are responsible for helping travelers to get information, change trains, buy tickets, etc. During a disturbance, they keep close contact with TIL, in order to get updated information for the travelers.

The traveler may also collect information from external sources. For instance, a travel planner for the whole of Sweden, called Resrobot, is provided by Samtrafiken. Resrobot is unique since it includes all trains, busses, flights, subways and trams in the country. However, as Skånetrafiken's travel planner, it does not replan in case of disturbances.

For less imminent disturbances, train operators are also able to apply for a specific train to be cancelled, in a system called Ankan ("Ansökan Kapacitet"). Trafikverket is responsible for collecting the application and decide whether or not the train should be cancelled. A system called TrainPlan shows whether the train was cancelled. The SJ travel planner has access to TrainPlan and uses it to collect information about cancelled trains. This latter information flow is not shown in Figure 1, since it only applies to SJ.

6.4. Disturbance process from the train operator perspective

This section is based on information provided and verified by Arriva. Arriva is currently responsible for some of the train lines in the identified scenarios, and Skånetrafiken acts as the ordering party toward Arriva.

As described in section 6.3, the TIS meetings are conducted over the phone. During these TIS meetings, the technique does not always work as well as it might, and Arriva therefore sometimes finds it hard to hear what is being said. Furthermore, Arriva misses TIS meetings from time to time, because of technical problems (e.g. the meeting invitation arrives too late).

Arriva suggests that train replacement buses are included in the disturbance plans. The disturbance plans should then be related to different times of the day (assuming there is no real time information about how many travelers are onboard the trains), since there is less need for train replacement buses during night. Arriva would also like to have the bus operators responsible for regular bus lines more closely involved in the disturbance process. The effects of the disturbances might then be mitigated.

There is a need for information about the number of passengers currently onboard a train, in particular in case of evacuation. It has happened that trains have broken down "in the middle of nowhere", forcing only one train attendant to handle the evacuation of a relatively large amount of passengers. These types of situations might be prevented if Arriva had information about the actual number of onboard passengers. Skånetrafiken has, however, recently installed a system for registering the number of travelers boarding and leaving a train. The system is currently being tested, and it might solve the above problem if Arriva is provided access to this information. Furthermore, the information could also be used for estimating the required train replacement bus capacity, in case of disturbance.

In order to improve disturbance management, Arriva would like access to real time positioning information about the trains. If all trains were equipped with GPS, which is not the case today, this could be solved.

As for information to the travelers, there is a problem with contradicting information. Järda might say one thing and the platform display another. Moreover, a train might be placed on a different track than announced by both Järda and the display. Travelers may also be confused when Trafikverket's web page says that trains are running as normal again after a halt in rail traffic, even though they are still heavily disturbed by delays due to the halt. Finally, like other traffic actors Arriva feels the displays and callouts could be more efficiently utilized. During heavy disturbances, the callouts from Järda sometimes lag behind because of the large amount of scheduled callouts.

Arriva suggests having one single centralized traffic management ("trafikledning"), instead of every operator having its own. This would both decrease duplication of work, and remove the need for educating new people whenever a new actor is engaged. Furthermore, everyone affected by a disturbance would then receive the information from the same information source, and at the same time if desired.

Arriva argues that one of the main problems today has to do with train and personnel planning. Today, trains are driven relatively large distances, before they turn around. This means that one delayed train has a relatively large impact on the overall traffic situation. A system based on shuttle traffic instead (similar to the way subways are operated), where each train is driven on one single, relatively short distance back and forth, would result in a more stable traffic situation.

Finally, Arriva would prefer more stable plans during disturbances. In particular, if trains are cancelled until a certain point in time, it may be hard to suddenly change these plans (e.g. because of other weather conditions than predicted) since both trains and personnel has been reallocated. Then it might be better to stick to the initial plan.

6.5. Disturbance process from the bus operator perspective

This section is based on information provided and verified by Nobina, since Nobina is currently responsible for the bus lines that may serve as alternative traffic routes in the identified scenarios.

Skånetrafiken acts as the ordering party toward Nobina. In this relationship, Skånetrafiken's TIC is responsible for the information flow to the travelers. The TIC is thereby also responsible for the information shown on the displays at bus stops. These displays informs travelers about departure times as well as delays and cancelled bus lines. The traveler also has access to disturbance-related information through Skånetrafiken's travel planner. On rare occasions, the traveler may, additionally, receive information from the bus driver or the Nobina traffic information center, via the bus speakers.

If a traveler contacts the TIC to report a bus-related disturbance (e.g. a bus not showing up), the TIC investigates the problem by calling Nobina. Nobina has daily telephone contact with Skånetrafiken, and most often, these calls concern disturbances reported by the travelers. On rare occasions, for instance if a road accident causes several cancelled bus lines, Nobina initiates a communication with Skånetrafiken to keep them informed about the disturbances. In general, Skånetrafiken is the only external actor Nobina communicates disturbances with, i.e. Nobina has no regular contact with, for instance, Trafikverket or other bus operators, regarding disturbances. However, if they through other channels discover some major disturbance, for instance if the police has closed a number of roads, Nobina actively starts seeking further information by calling different actors and searching the web.

Today, Nobina applies, so called, connecting buses on some lines, which means that one bus has to wait for another bus to arrive (within reasonable time limits), before it may leave a bus station. This way, the travelers are guaranteed not to miss the next bus, even if the current bus is delayed. However, there is no corresponding service between buses and trains, i.e. buses do not wait for certain, delayed trains to arrive. Furthermore, extra buses are almost never engaged on regular bus lines, as a consequence of train disturbances (since they are not engaged during train disturbances). The interviewed person at Arriva further illustrates this by stating that their regular buses never have to leave passengers behind due to overcrowded buses caused by train disturbances. There are several reasons for why Nobina's regular bus lines are not extensively utilized for mitigating train disturbances. On the one hand, the train travelers do not receive any directed information about suitable regular bus lines, which could be used as alternative travel solutions during a train disturbance. On the other hand, Nobina lacks up-to-date information about train disturbances. In particular, they receive no such information from Skånetrafiken or Trafikverket, which means that they only obtain this type of information by searching web pages or if someone calls (e.g. a driver). In order to get more updated information, Nobina would like to have access to TLS chats between Skånetrafiken and the train operators (see section 6.3).

The traffic information center at Nobina works with a system called OCA, which the TIC also has access to. In OCA, Nobina may cancel busses, and when they do, all affected information displays on the bus stops, as well as Skånetrafiken's travel planner, are updated with this information. This means that the TIC does not have to communicate this particular type of information to the travelers. Furthermore, since the TIC has access to OCA, they also receive notifications about the cancellations. OCA operates in real time, meaning that it shows all buses and corresponding disturbances (e.g. delays) in real time. The drawback with this real time system is that buses which should have already arrived to the end destination according to schedule, cannot be cancelled (since they are not shown in OCA anymore). Hence, travelers waiting at the second last stop of the line will not get any cancellation information.

OCA is dependent on another system called OBIS, which keeps track of all buses. OBIS is also used for displaying the next stop to onboard travelers. This means that whenever OBIS gets connection problems, the onboard travelers do not receive any real time bus stop information. Furthermore, since no bus tracking information is produced, the TIC loses access to real time bus traffic information, which means that the travel planner cannot be updated with corresponding real time information. Therefore, most calls to the TIC received from the travelers are attributed to OBIS connection problems.

A system called VoIP is used for communications between the Nobina traffic information center and the bus driver (e.g. concerning traffic diversions). Both oral and text-based communication are supported. This system also allows for the rarely used call-outs to onboard travelers, described above. Additionally, VoIP can be used for driver-to-driver communications. However, this functionality is rarely utilized. Skånetrafiken has no direct access to VoIP, and thereby they have no communication links to the bus drivers.

The traffic information center at Nobina works with an additional, internal system called OMS. All disturbance-related information is registered in more detail in OMS (including both cancellations and delays). Nobina shares this information with the TIC by emails, which are created and sent upon demand by OMS. For instance, if OBIS has connection problems (which occurs from time to time), the traffic information center at Nobina might get disturbance-related information through VoIP instead. This information is then manually inserted into OMS, which upon demand sends an email with the corresponding information, to the TIC. OMS allows for cancellation of a bus in advance, i.e. before it has finalized its route. This is not possible in OCA since it operates in real time, as described above.

6.6. Disturbance process from the taxi operator perspective

The interviewed taxi operator has no communications with other actors regarding disturbance-related information. However, taxi drivers continuously communicates with each other. For instance, when large disturbances take place, crowds have formed, or police controls have been detected, the taxi drivers inform each other. This information flow is very efficient. During train disturbances, they often experience travelers choosing taxi instead of waiting for the train.

7. Required information availability

7.1. Identified information-related problems

During our interviews, a number of information-related problems and improvement potentials related to regional rail traffic disturbances in the southern part of Sweden, have been expressed. These are listed and described below. All problems from the interviews have been verified by the information providers, i.e. the interviewees. The information-related problems and improvement potentials expressed at the workshop are also included in the list below. This latter information has been written by the group leaders themselves. Since the report focus is on information flow between actors and to/from travelers, purely internal problems have not been considered.

Problems expressed by Trafikverket and Skånetrafiken:

- P1. Skånetrafiken claims that around 80% of their travelers are pleased with their latest journey; however, only 25-30% are satisfied with the provided traffic information during unplanned disturbances.
- P2. Different actors use different computer systems which do not communicate with each other. Therefore, most of the information is transmitted via telephone calls, which is not efficient.
- P3. There is no support system for registering information related to disturbances, during the actual disturbance. Instead information has to be registered retrospectively.
- P4. Skånetrafiken has to wait until the first TIS meeting, or even longer, before they get any prognosis. Before the prognosis, they only have statistics to work with when informing the travelers. The information delay causes different people to call the entrepreneur to get the prognosis as soon as possible (he/she may get up to 60 calls during a disturbance), which means that the work with solving the problems is slowed down. In order to prevent this and to speed up the information process, there should be an instant electronic communication about the prognosis.
- P5. Trafikverket has a hard time to keep up with all the things that have to be done before the first TIS meeting (e.g. manual information handling).
- P6. Station hosts sometimes call Trafikverket several times during a disturbance, in order to get updated information. These calls consume a lot of time from Trafikverket.
- P7. Today, there are mainly three different actors who informs the traveler about train deviations: Skånetrafiken, Trafikverket and the train operator. This means that these actors must make efforts to ensure that the information is consistent (i.e. that there are no discrepancies, which sometimes is the case today).
- P8. Travelers sometimes complain about the lack of real-information related to train replacement buses (e.g. a display on the bus stop showing the bus arrival time). The information connection to the traveler is often lost when the traveler leaves a train, and the local displays on the bus platforms usually do not show information regarding train replacement buses. It has happened that buses have run empty from one place to another, only because the travelers did not know from which point the bus left.
- P9. Some travelers might miss announced information about a disturbance, for instance if they are wearing headphones.
- P10. The information displays inside the trains are not utilized enough. In particular, they should be used more extensively to provide disturbance information. The information displays inside the trains are controlled by Skånetrafiken.
- P11. Today, there is no information about the amount of travelers waiting on a platform for a train replacement bus, or onboard a certain train. Information about the types of travelers is thereby not available either (e.g. if there are school classes onboard). Such information would enable better planning. For instance, the bus capacity on regular lines, or the priorities

made between different trains during a disturbance could be adapted to the number and types of travelers.

P12. There is a lack of communication regarding where different train drivers currently are. For instance, one train driver might have to go by taxi from city A to city B, during a stop between these cities, while another train driver goes by taxi in the opposite direction, from city B to city A, in order to drive further. Instead they could have stayed and driven each other's trains. Information of whether a train currently lacks a driver, may also be poorly communicated. Furthermore, such lack of information related to train drivers sometimes leads to insufficient traffic information to the travelers.

P13. Some train drivers use an ecodriving-application, which helps them optimize the speed of the train, given the scheduled time of arrival. If a train is early, the dispatchers might assume that the train will arrive to a train station earlier than scheduled. If the train is driven with ecodriving, the train instead arrives at the time scheduled. This may ruin the dispatchers' plans. Trafikverket would therefore like to get information about which applications the train drivers use.

P14. It is difficult to handle revised versions of the disturbance plans, since there are many actors involved (26 in total) and there is no common electronic storage for the plans.

Problems expressed by the train operator Arriva:

P15. The train replacement buses are often tourist buses, which sometimes are driven by chauffeurs with limited knowledge of local roads.

P16. During the TIS meetings, there are sometimes problems in hearing what is actually being said. The train operator also misses TIS meetings from time to time, because of technical problems (e.g. the meeting invitation arrives too late).

P17. The bus operators responsible for regular bus lines are not enough involved in the disturbance process. If they were, the effects of the disturbances might be mitigated.

P18. The train replacement buses are not included in the disturbance plans, which means that new decisions have to be taken every time train replacement buses are needed.

P19. The train operator needs information about the number of onboard passengers, both in case of evacuation (in order to have enough personnel to handle the passengers) but also to be able to order enough train replacement bus capacity.

P20. There are several problems related to inconsistency and deficiency in the traffic information provided to the travelers. For instance, the announcement system might say one thing while the platform displays says another, and a train might be placed on a different track than announced by both the announcement system and the displays.

P21. In order to improve disturbance management, the train operator would like access to real time positioning information about the trains, including when trains are not nearby a train station.

P22. The train operator would have liked to have one single centralized traffic management, instead of every operator having its own. Everyone affected by a disturbance could then receive information from the same information source, and at the same time if desired.

Problems expressed by the bus operator Nobina:

P23. The bus operator and the TIC communicates bus-related disturbances frequently via telephone. If they would communicate via some digitalized communication tool instead, the communication would be more efficient.

P24. The bus operator receives no disturbance-related information concerning trains. If they, for instance, had access to the chat initiated by Trafikverket (see section 3.1), they would be able to provide better support during train disturbances.

P25. If the bus operator had access to the disturbance plans, they would have been able to provide better support during train disturbances.

P26. The bus operator has no information about to where train travelers are heading. If they knew, bus drivers could be told to wait for certain trains, during disturbances.

P27. Today, many actors may be affected by a disturbance but there is no common information system. Such a system could serve as support for all actors during the disturbance, by improving cooperation and assuring they all work in the same direction.

Problems expressed by several public transport actors at a common workshop organized by Samtrafiken:

P28. Different actors have different travel planner apps. This means that travelers using transport services from several actors are forced to use several different apps to find updated disturbance-related information.

P29. Today, there is no common view on when to inform the travelers (e.g. whether they should be informed after 3, 5, 10 or 20 minutes delay, at the latest), which may cause wrong expectations among travelers using transport services from several actors.

P30. Public transport actors often wait until they have reliable prognoses, before disturbance-related information is communicated to the traveler. This means that the travelers get frustrated and start searching for other sources of information. The travelers need honest and frequent information in order to make the right decisions, even if the prognosis is weak. For instance, even if there currently is no information, the travelers need to be notified (e.g. more information will be available in 5 minutes).

P31. Different travelers use different information channels, which may not provide the same information. A common flow of information is needed.

P32. All travelers must receive disturbance-related information. This is not always the case today. For instance, different travelers use different information channels, which means that disturbance-related information must be provided in all these information channels (e.g. web page, app, displays, and personal contacts). Furthermore, some travelers are difficult to reach at all, for instance due to headphones.

P33. Different communication channels use different vocabulary.

P34. Disturbance-related information should be given in several different languages.

P35. Different modes of transport provide different types of disturbance-related information.

P36. The information provided concerning disturbances and train replacement buses is insufficient. For instance, the inside and outside information displays must provide better information.

P37. Information about alternative travel routes are not, but should be, provided to the travelers during a disturbance. The traveler should be allowed to make his/her own travelling decisions during disturbances, based on individualized information, otherwise they will lack a sense of control. For instance, the prognosis for when a train replacement bus arrives should be communicated, along with other travel alternatives.

P38. Some travelers find it hard to know who to turn to for help/questions during disturbances.

P39. Information about cause and consequences must reach relevant personnel sooner, during a disturbance.

P40. In general, the communication between rail traffic and bus traffic needs to improve, in order to promote collaboration.

P41. Today, there is often no information about where onboard travelers are heading during a disturbance. Such information would allow for improved disturbance management.

P42. All trains should be provided with GPS, in order to get real time positioning information. This would allow for improved disturbance management.

P43. If all traffic actors would get information about the other public transport actors' activities (including bus operators), the actors would be allowed to cooperate more. In particular, passenger exchanges during disturbances could be increased.

7.2. New law on travelers' rights (2015:953)

A new law concerning the rights of the public transport travelers, came into force in Sweden on April 1, 2016 (Sveriges Riksdag 2015). Since it affects the transport operators' responsibilities to the traveler in case of disturbances, we briefly describe and discuss the law below (with focus on the disturbance perspective). A transport operator is, in this case, the railway company with which the traveler has a transport agreement (e.g. Skånetrafiken or SJ).

7.2.1. Description

The law concerns travel information, compensation and price reduction due to disturbances, or broken agreements connected to period tickets, in public transports with train, tram, subway, bus or car (Sveriges Riksdag 2015). The parts of the law most relevant for our focus, can be described as follows:

- L1. According to the new law, the transport operator is obliged to provide information about a disturbance, including what caused it, how long it will last and its consequences. The transport operator must also provide information about traveler rights, contractual terms, ticket prices, time tables, lines, accessibility in vehicles, on stations, and on bus stops, bicycle possibilities, security issues, and how to contact the transport operator. The information must be provided in the, for the traveler, most suitable way.
- L2. The law also states that if there is reasonable cause to believe a journey will be more than 20 minutes delayed, the traveler is entitled to compensation from the transport operator, for all reasonable costs for reaching the final destination by other means of transport. This applies even if there is no agreement related to the particular journey that is feared to be delayed, if the traveler has specifically conformed to the journey. A journey may, in this case, involve one or several transport operators.
- L3. If a journey is more than 20 minutes delayed, and if the traveler does not make a request for compensation for other means of transport (according to above), the traveler is entitled to price reduction. The price paid by the traveler for the journey is then reduced by 50% if the delay is longer than 20 minutes, 75% if the delay is longer than 40 minutes, and 100% if the delay is longer than 60 minutes.

7.2.2. Discussion

According to the new law, certain information must be provided to the traveler, by the transport operator. We believe that information related to a disturbance can be delivered to the traveler through the same channels as the other information mentioned in the law. This is possible if a web page or an application is used as interface to the information. The main advantage with this solution is that the traveler receives all necessary information through the same interface. The traveler is hereby able to make use of different types of information, in combination, during a disturbance (for instance, to read about traveler rights based on disturbance information). A web page or an application is not enough to reach all travelers, though, since they may not all be equipped with smart phones (or similar). Complementary interfaces must in this case be provided, given that the information must be provided in the, for the traveler, most suitable way.

Since delays of more than 20 minutes costs money, transport operators might start making more efforts to find alternative travelling solutions that are as cheap as possible. In particular, this may create incentives for better traveler support in terms of how the traveler best can reach his/her individual final destination, during a disturbance. For instance, travelers using period tickets could be directed to alternative means of transport, which could prevent these travelers to reach the 20-minutes limit. Given that these alternative means of transport are driven according to ordinary time tables, the disturbance-related costs stipulated by the new law would be eliminated. Furthermore, it would also raise the customer satisfaction. Other types of travelers, not using period tickets, could also be directed to other means of transport, depending on costs and availability. Before deciding how to handle these travelers, costs for different alternative solutions, together with the consequent costs raised by the new law, must be evaluated and compared.

7.3. Missing information

Based on the problems identified in section 7.1, and the new law described in section 7.2, the following information and communication processes have been identified as missing for different stakeholders, in the current system:

Traveler:

- M1. Sufficient traffic information during unplanned disturbances provided to the traveler as fast as possible, or at a frequency commonly agreed between all actors (including what caused the disturbance, how long it will last, its consequences and prognosis reliability). Information should be provided even if its content is sparse or reliability is weak. (P1, P29, P30, L1)
- M2. Information other than disturbance-related, listed by the new law. For instance, clear information about who (and how) to contact in case of questions related to a disturbance (P1, P38, L1)
- M3. Information provided in the, for the traveler, most suitable way. For instance, disturbance-related information should be shown on the information displays inside the trains, and information concerning train replacement buses should be shown on the displays on the bus platforms. Travelers using headphones should also be reached. (P1, P8, P9, P10, P32, P36, L1)
- M4. Disturbance-related information from only one involved actor (vertical organizational plane, e.g. Trafikverket or Skånetrafiken), or alternatively highly coordinated information from several actors. (P1, P7, P22)
- M5. Similar types of disturbance-related information irrespective of transport mode. (P1, P35)
- M6. Highly coordinated information from different media, e.g. platform displays, platform announcements, and the web pages. (P1, P20, P31)
- M7. Disturbance-related information in several different languages. (P1, P34)
- M8. Similar information, vocabulary in travel planners and other communication channels. (P1, P33)
- M9. A travel planner that provides disturbance-related information from as many transport operators as possible (horizontal organizational plane, e.g. different train operators). (P1, P28)
- M10. Several alternative travel routes, including estimated travel times, provided during disturbances. Prognoses for any train replacement buses should be included. (P1, P37)

Skånetrafiken:

- M11. Information to Skånetrafiken about the prognosis as soon as it is available. (P2, P4, P39, L2, L3)
- M12. Information about previous prognosis states, including previously suggested routes to final destinations (In order to determine whether there has been reasonable cause to believe a journey would be more than 20 minutes delayed, as stated by the new law) (L2, L3)

Trafikverket:

- M13. Possibilities to register information related to disturbances (e.g. decisions, events), during the actual disturbance. (P3, L2, L3)
- M14. More automated information processes before the first TIS meeting. (P5)
- M15. Information about train drivers' whereabouts. (P12, P39)

M16. Arrival time updates agreed between train drivers and dispatchers for trains that may arrive earlier than stated in the time table (e.g. to remove problems related to ecodriving). (P13)

Station hosts:

M17. More efficient information flow to station hosts. (P2, P6, P39)

Entrepreneur:

M18. Only one external contact for the entrepreneurs during disturbances. (P4)

Train operator:

M19. Real-time positioning information about all trains, including when trains are not nearby a train station. (P21, P42)

M20. Information in the disturbance plans concerning when and how many train replacement buses should be hired during disturbances (depending on, e.g., the time of the day). (P18)

M21. Improved communication technology, when Trafikverket communicates with the other actors during disturbances and TIS meetings. (P2, P16, P22)

M22. Information about capacities in regular bus lines during a disturbance in order to mitigate the effects. (P40, P17)

Train replacement bus operator:

M23. Sufficient information/knowledge about local road networks (sometimes missing when tourist buses are hired as train replacement buses). (P15)

Bus operator:

M24. More disturbance-related information (including both real time information and disturbance plans) concerning trains, in order to be able to involve regular bus lines in the disturbance process. (P17, P24, P25, P39, P40)

M25. More efficient (digitalized) communication between the bus operator and Skånetrafiken. (P2, P23)

Trafikverket, Skånetrafiken, train operators and bus operators:

M26. Information about where people are traveling and when, during a disturbance (e.g. waiting on a platform or onboard a train). (P11, P19, P26, P41, L2, L3)

M27. Revision system for the disturbance plans, which can be reached by all actors involved. (P14)

M28. In general: shared information about disturbance cause, consequences and actions taken, between all actors during a disturbance. This would promote cooperation and assure they all work in the same direction. (P27, P39, P43)

8. Potential solution approaches

This section elaborates on potential solution approaches for collecting the missing information and introducing the missing communication processes, described in section 7.3. The ideas presented are based on analysis, literature studies, and ideas from the interviewees and the work shop. Some of the proposals may not be feasible due to competitive reasons (between different actors) – these issues remain to be investigated.

8.1. Common information system

In order to increase information transparency and improve services, one approach could be to use a common information system, see Figure 3. In this report, we describe the approach as one common system, however, in reality, two interconnected systems may be needed: one directed towards the actors and the other directed towards the travelers. Mejía et al. (2015) describe a similar solution for an integrated public transport system – a technological web platform, which has two access portals, one for the traveler planning his/her journey, and one for the platform manager creating optimal time tables etc. The platform allows for different actors to access information necessary for effective decision-making, in real time (Mejía et al. 2015).

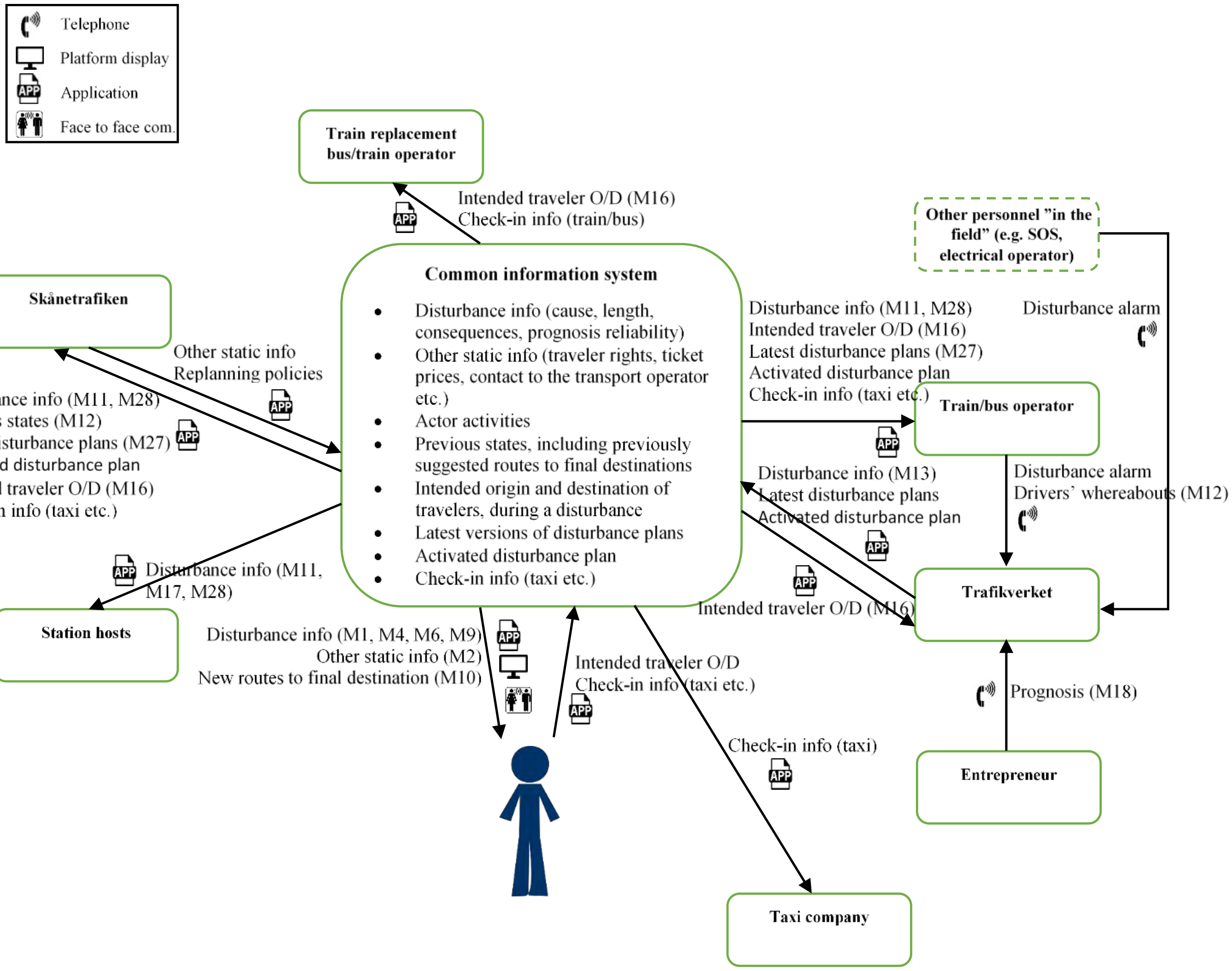

Figure 3 Suggested solutions, with references to the missing information and communication processes

As before, the disturbance management process starts with a phone call to Trafikverket. Trafikverket then inserts all disturbance-related information currently available, in the common information system for all actors to reach (including e.g. bus operators). The information should include what caused the disturbance, how long it will last, its consequences (with an explicit reference to a disturbance plan, if relevant) and prognosis reliability. Since it is important for the actors to receive this information as quickly as possible, Trafikverket must continuously update the system as soon as new information is available.

The common information system is also fed with static information, in accordance with the new law (cf. M2), e.g. by Skånetrafiken. The traveler could receive parts of this information, as identified in M1 and M2, using a travel planner app common for at least the actors involved. The app thereby provides dynamic information about the disturbance (including cause, length, and consequences), and static information (listed in the new law) to the traveler (cf. M1, M2). The primary benefits of using a common information system and app for these things are firstly, that all actors get the same information as soon as it is available (cf. M11, M17, M28), and secondly, that travelers get contact and disturbance-related information for several transport providers (e.g. for their whole journey, even if it involves transport services from several transport actors), from only one source of information (cf. M1, M2, M4, M9).

Given the updated disturbance information in the common information system, the travel planner app should describe alternative ways for how the individual traveler's journey can be replanned, with account taken to any new traffic conditions caused by the disturbance (including train replacement buses) (cf. M10). In order to minimize the compensation/price reduction costs associated with the new law, Skånetrafiken may use this information to promote specific routes, in an optimized way (i.e. finding an optimal balance between delay costs and transport costs) (cf. M12). For instance, under certain circumstances, it might be less expensive to order train replacement buses than paying compensations and price reductions. From a traveler perspective, different alternative routes are presented, and the corresponding costs for the traveler, when the transport operator has paid its share according to the new law, for each of the alternatives, are also presented. The route alternatives might be based on, amongst others, the current information about the disturbance and corresponding activities (including ordered train replacement buses), and the selected disturbance plan, all of which are stored in the common information system. The disturbance plans should therefore be digitalized. If they are, the consequences of activating them could be utilized automatically in the replanning process. The activated disturbance plan, and the latest revision of each plan, should always be electronically reachable by all actors involved (cf. M24, M27). Moreover, if they were accessible for external actors as well (e.g. third party companies), new types of services might pop up.

The common information system enables the communication channels towards the travelers, e.g. the displays (handled by Trafikverket), the travel planner app (handled by Skånetrafiken) and the onboard personnel (employed by the train/bus operator), to retrieve disturbance-related information from the same source. That is, different types of media used for communicating the information may utilize the same information source (cf. M6). This implies a decreased risk of information discrepancies. Furthermore, a common information system and travel planner app facilitates common improvements in terms of support for different languages, similar types of provided information irrespective of transport mode, and similar vocabulary (cf. M5, M7, M8).

The common information system should be reachable for all public transport involved and affected by a disturbance, including actors operating different modes of transport that may serve as alternatives during the disturbances. Our investigations show that there are potential benefits in having the bus operators more closely involved in the disturbance management process. If they are provided access to the information in the common information system, the cooperation between the train and bus operators may increase (cf. M24, M28). In particular, exchanging real-time information about a disturbance and the current regular bus line capacities, is a prerequisite for utilizing the bus lines during disturbances. The forms for this type of cooperation can be specified in the disturbance plans (on a general level) and discussed at the TIS meeting (on a more specific level) (cf. M22, M24). We therefore also suggest that the relevant bus operators are included in the TIS meetings. Moreover, if the regular bus lines are engaged in the disturbance management process, the need for ordering train replacement buses may decrease (cf. M23).

Finally, the common information system could be used for a number of other improvements, as well. For instance, a lot of the activities performed by Trafikverket before the first TIS meeting may be facilitated or even removed, if the common information system was used for providing information to all actors involved (cf. M14). The system would also improve the communication process during disturbances and around TIS meetings (cf. M21). Since the common information system holds the latest prognosis, the need for other actors to contact the entrepreneur themselves, is decreased (cf. M18). Trafikverket could thereby continue to act as the (only) contact to the entrepreneurs. Additionally, the common information system can be used by Trafikverket for registering and storing information related to a disturbance (as an archive to be used at later occasions), during the actual disturbance (cf. M13).

8.2. Check-in system

Our investigations show that information about where and when people are traveling is requested (cf. M26). Since Skånetrafiken applies both monthly smart card tickets and single tickets, this type of information must be collected some other way than just registering tickets. If automated detection is used (based on sensors), information about the number of travelers on a specific vehicle or platform can be obtained. This type of information is valuable, for instance, when ordering train replacement buses. However, if some sort of check-in system is applied, information about which travelers are currently onboard, can also be obtained. This type information is needed by Skånetrafiken when travellers apply for compensation or price reduction according to the new law (cf. M12); however, the information must be highly accurate in order to be useful for these type of purposes. Such a check-in system could be extended to also incorporate information about the traveler's origin and destination, and perhaps also the type of traveler, e.g. child or someone with special needs (cf. M26). This type of information may be valuable to several actors involved. Skånetrafiken need the information for the same reasons as why the prognosis is needed, i.e. to suggest appropriate alternative routes to the travelers, and to plan for actions due to the disturbance. Trafikverket needs the information to enable better planning, for instance, when making priorities between different trains. Train replacement buses and trains can utilize the same information to prepare for orders from the train operator.

In addition to knowledge about where and when people are traveling, we believe a check-in system can be used for collecting information about how travelers change their plans during a disturbance. Such a check-in system could be integrated with the common travel planner app. When the traveler selects (checks in on) one of the alternative routes provided by the app, this information is stored in the common information system. The information may then be used by, for instance, train and bus operators when calculating the number of train replacement buses needed, or when deciding whether some specific regular line traffic should be provided with larger buses. In particular, we believe that this type of check-in system can be valuable for taxi operators, who could offer shared taxis at a lower price. Taxi transport would thereby also be included in the alternative routes presented to the traveler. By using the common travel planner app, the traveler could check in on a taxi ride, shared with other travelers affected by the disturbance. The research community has produced a number of studies on a similar concept called Demand Responsive Transport (DRT) (Giannopoulos 2004). In DTR, passengers share a vehicle, for instance a small bus, which pick up or drop off the passengers at passenger-specified locations and times (Ronald et al. 2013). Initially, DTR was designed for disabled or elderly people; however, it is now seen as an interesting solution for increased access and flexibility in public transport, for the whole community (Nelson et al. 2010; Dias et al. 2012).

There might be problems with check-in systems as well. For instance, travelers may be reluctant to check in due to privacy and safety concerns. Investigating travelers' opinions on this topic is out of the scope of this report; however, we do acknowledge that there might be a problem and that it is important to make sure there is true value for the traveler to use such a system. There are ways of solving these issues by not storing the information that enables relatively easy identification of individual travelers. Furthermore, since travelers already are used to check-in systems for certain types of travels, e.g. flight and ferry transports, this may not be an issue at all.

In practice, a mandatory, locally placed check-in system may, for instance, be applied if highly accurate information is required; otherwise, a voluntary check-in app can be used (e.g. integrated with the common travel planner app, described above) (cf. M26).

8.3. Other potential solution approaches

The common information system and travel planner app, and the check-in system described above, do not cover all missing information and communication processes listed in section 7.3. For some of them, individual solutions are required.

If the train/bus operator could find routines for informing Trafikverket about the drivers' whereabouts, as well as which train drivers use eco driving, some of the prognoses could be improved, and the dispatchers' work would be made easier (cf. M15, M16). Furthermore, the disturbance management process would be improved if the train operator had access to real time positioning information about the trains. This would also improve the information to the traveler, e.g. concerning the estimated time of arrival information (Camacho et al. 2013). All of the trains should therefore be equipped with GPS (cf. M19). Furthermore, if the disturbance plans were complemented with information regarding when and how many train replacement buses should be hired during disturbances, the disturbance management process would probably speed up (cf. M20). Finally, the bus operator is in need of a more efficient communication channel to Skånetrafiken. Since this communication is frequent, we suggest that a common chat is used (cf. M25).

The new law says that information should be provided to the traveler in the, for the traveler, most suitable way (cf. M3). Our investigations suggest that the displays inside the trains could be used for showing disturbance-related information, and the bus platform displays could be used for showing information about train replacement buses (cf. M3). We therefore suggest that all displays inside trains and buses, and all bus/train platform displays are used for showing disturbance-related information. In general, several projects have shown that real-time information displays are appreciated by the travelers (Dziekan & Kottenhoff 2007). In addition to displays, we suggest that all information is provided by the apps as well. This way, the travelers who lack access to the apps, get information on the displays, and the travelers with headphones may seek information from the app, whenever he/she wants (provided they have access to internet). All travelers who cannot be reached in any of these ways, for instance sleeping passengers, should be informed by the onboard personnel. Finally, the information provided by the onboard personnel and by the apps, can be more tailored towards the individual traveler needs, than the information provided by displays. Therefore, we suggest that the displays show as detailed information as possible. For instance, new routes to all larger connection points which may be the destination of many of the travelers, could be provided by the displays.

9. Discussion and conclusions

This report has presented a map over the current information flows within and between different public transport actors, during unplanned disturbances. Additionally, the problems and missing information and communication flows, in the current systems have been identified. A new Swedish law which strengthens the traveler's rights to information and to compensations for disturbances that are expected to last more than 20 minutes, has also been taken into account. Finally, a common information system and a traveler check-in system were proposed as the main solutions to solve these issues.

Tyrinopoulos (2004) claims that the main problems that currently exist due to the lack of an effective mechanism of IT applications integration in the public sector are: incompatibility between applications, insufficient information flow, multiple storage of common datasets, delays in information availability, and high operation and maintenance costs of the applications. Our investigations confirm a lack of all, except the last, of these. Furthermore, Zito et al. (2011) have studied the provision of real-time information, which may be used by travelers for making more informed decisions regarding their mode of travel, planned routes and travel times. The study shows that this type of information has the potential to increase the use of public transport. These two studies imply a need for improvements, both from the information system aspects, and from the traveler information aspects.

The train operator we interviewed, would have liked to have one single centralized traffic management, instead of every operator having its own. Outside of Sweden, several joint control centers have already been established by infrastructure managers and operators (Sørensen & Longva 2011). The purpose of these centers is to deliver effective real-time management of planned and unplanned disruptive events. The idea is to overcome the problems connected to the separation of train and track, induced by deregulations.

Even though our case concerns a rather limited geographical area and in a Swedish setting, we believe that our findings, and in particular the suggested approaches, are relevant for other transport systems in the world, since some characteristics are rather general and commonly present:

- Correct and quick information to travelers about the transport system and in particular information of how the traveler can get to the intended destination in case of disturbances is always of importance.
- More knowledge about where travelers are and their intended destination is always of potential use in the transport system operators.
- Information exchange between different operators is typically underutilized particularly of intended and taken action in case of disturbances.
- In cases where the public transport system is operated by a single operator, we believe there is still often lack of information sharing between operations of different modes, e.g. buses and trains within the organization.

10. Related projects

Resenärsmeddelande (Trafikverket)

This project has investigated how to provide the traveler with better train traffic information during disturbances. The project concludes that the major problems within this area can be related to the lack of a more digitalized process. Today, most of the information is transmitted via telephone, either between two parties or several by means of conference calls. A more digitalized process is believed to raise efficiency and transparency, as well as allow for better follow-ups and continuous improvements.

TID (Trafikverket) (no decision yet)

This project has not been approved yet. It mainly represents a continuation of two former projects focused on train replacement traffic (called ”Ersättningstrafik”) and information to the traveler (called ”Resenärsmeddelande”, see above). It also includes former work with a common disturbance process (Trafikverket 2015d). Within this work, the process and requirements of a shared issue tracking system, have been identified. Amongst others, the requirements of the issue tracking system specify how the travelers' aspects should be integrated with the system. Alternative routes are also included in the system; however Trafikverket is mostly concerned with different traffic links, not a traveler's whole journey from origin to destination, with several line changes. Skånetrafiken and SJ are more concerned with the latter. The primary aspects that TID is expected to contribute with is the digitalization and system solution, which assembles data. The project requirements description is based on a process concerning the train traveler's journey (called "Resenärens tågresa"), which includes what information is available at different stages (for instance, when the traveler reaches the train station to begin a journey).

OLS (Trafikverket) (no decision yet)

This project has not been approved yet either. OLS (”Operativt ledningssystem”) focuses on a new operative management system. The new system is expected to primarily facilitate the communication between regional and national operative managements, as well as production leaders (working as the extension of the regional leaders) at Trafikverket. The system will collect information from the existent systems at Trafikverket. It is supposed to be in operation at the beginning of 2017. Trafikverket will set up a group of system architectures to investigate how OLS and TID will interoperate.

NTL (Trafikverket)

NTL (”Nationellt Tågledningssystem”) aims at common working routines for traffic control, in order to obtain better overview, more flexibility, and more efficient control and surveillance. The final goal of the project is a new nationwide IT solution for traffic control, where all Swedish rail parts are operable from each place where traffic control is performed. One of the problems today is that different traffic control systems do not communicate. This means, for instance, that when a train leaves Gothenburg for Stockholm, it is not visible to TC Stockholm until it reaches their district – in this case when less than a third of the journey remains.

Regarding disturbances, the new system will provide support to dispatchers when they reschedule trains. Today, this rescheduling is done by pen and paper. Additionally, the new system will decrease the risk of disturbances, by help improving the initial time tables. The whole project is expected to finish during 2018, after a step-wise introduction of the new concept of nationwide traffic control, starting in 2016.

Prestudy: Realtid i Samverkan (Samtrafiken)

Samtrafiken has been involved in a prestudy concentrating on real time information in public transport, with focus on the needs of the individual traveler (Samtrafiken 2014). Amongst others, the prestudy advocate a traveler decision support that is operator neutral and includes several modes of transport during one journey, for instance bicycle and public transport in combination (Fusale 2014). Furthermore, it suggests that third-party developers get access to traffic data to enable new types of applications or integrations of the data into existent services. For instance, the information should be integrated with the infotainment systems inside cars, in order to provide car drivers with alternative public transport solutions in case of traffic congestion. Collecting information about deviations from travelers, is also mentioned as a viable approach in the prestudy. The prestudy claims that we have a long way to go to reach a position where the traveler can see the full effect of traffic not run on time (i.e. how the entire trip is affected).

The work related to the prestudy is currently suspended (Samtrafiken 2014).

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Appendix

1. What types of disturbances do you experience (magnitude and effect), and for each type of disturbance:
    a. How/from whom is information about the disturbance received?
    b. What actions are taken?
    c. What information is communicated to the travelers and actors (to which actors)?
    d. What information is missing and why?
2. Are there actions that could be taken (that are not taken today), and if so, what information is missing and what other obstacles exist for these actions?
3. Would it be possible to use information from the travelers, and if so, what information and how?
4. What plans for changes/improvements exist concerning disturbances?
5. (Do you know of any other persons or roles that would be interesting to interview?)

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