

Planning for the Unplanned: An International Review of Current Approaches to Service Disruption Management of Railways

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Abstract

This research paper explores the manner in which passenger rail transit organisations plan for and manage unplanned service disruptions through an international survey of practices. This included semi-structured interviews of those staff responsible for service disruption management within 48 international passenger rail transit agencies.

Results suggest that only 11% of agencies had parallel transit systems which can be used for riders on disrupted services. Most of these were in inner urban contexts. Track intrusions/ medical emergencies, weather extremes, track and rolling stock failures were common causes of unplanned disruptions. Bus bridging was the most common response to line blockages whilst transfer of passengers to the next train was the most common approach to individual train rolling stock failures. Track crossovers were widely seen as critical to managing responses to disruptions, however, a small minority in mostly very cold and freezing climates also saw crossovers as a cause of unplanned failures. Most agencies used available spare buses to source bus bridging vehicles, however, just over 40% actively retracted buses from existing scheduled bus services. It is rare for agencies to have a strategic reserve of buses for bus bridging purposes.

The paper discusses the implications of the study findings for future research and practice.

1. Introduction

Rail transit networks provide high-capacity performance compared with other transport alternatives in cities with high levels of road congestion (De-Los-Santos, Laporte et al. 2010). Unfortunately trains do not always run on time or at all due to unexpected events such as infrastructure malfunctions, accidents and extreme weather conditions. Such events are called disruptions (Jespersen-Groth, Potthoff et al. 2009). These events can lead to the rapid degradation of the provided service (Kepaptsoglou and Karlaftis 2009) and the results of such impediments can be significant. "When no advance preparations are made, uncoordinated Government responses can combine with tremendous public confusion and uncertainty to leave the urban transportation system in a state of near paralysis" (Meyer and Belobaba 1982, p.1).

A recent example occurred in Singapore in December, 2011. In the period of one week, the SMRT Corporation experienced three train breakdowns on its part of the city's Mass Rapid Transit network (Reuters.com 2011). Affecting approximately 350,000 commuters (Reuters.com 2011; Sim 2011), the three disruptions led opposition MP Lina Chiam to state, "Public transport can paralyse the entire nation from what we have seen a few days ago" (Reuters.com 2011). Many commuters commented that the incident demonstrated the lack of public information regarding contingency plans. The events resulted in the resignation of SMRT Corporation Chief Executive Officer Ms. Saw Phaik Hwa (Sim 2011).

Despite the critical impacts which rail disruptions can have, few studies examine the effectiveness of alternative ways to accommodate disrupted travellers (Janarthanan and Schneider 1984; Tsuchiya, Sugiyama et al. 2006).

This paper describes the results of an international review of current practices in the management of unplanned rail disruptions. It documents current industry approaches to this problem, how such disruptions are managed and highlights how agencies 'plan for the unplanned.' The paper commences with a summary of relevant literature. Survey methodology and approaches are then described including the categories of questions asked. This is followed by an outline of the major results. The paper concludes with a summary of key findings and a discussion of their implications for planning and practice.

2. Research Context

The operational performance of railway systems is increasingly a cause for debate publicly (Jespersen-Groth, Potthoff et al. 2009). Commuters expect to arrive at the published time, however, any service disruption can result in the degradation of the railway system's capacity resulting in unsatisfied demand and trip delays (Kepaptsoglou and Karlaftis 2010).

A disrupted situation is an operational state where the variation from an original plan is significant to necessitate re-planning (Clausen 2007). From the perspective of the airline industry a disruption can be defined as an event or series of events that renders the planned schedules for aircraft and/or crew infeasible (Clausen, Larsen et al. 2010). In the context of this paper this definition will be applied by replacing the term "aircraft" with "rolling stock". A delay is simply one result (incident) of a service disruption (Kepaptsoglou and Karlaftis 2009).

Schmocker et al. (2005) categorised three incident types: slow-moving delays, minor incidents and major incidents. Slow-moving delays result in speed and capacity restrictions, whilst minor incidents are often commuter-related. Major incidents commonly result from rolling stock or fixed infrastructure problems and are likely to close track sections. Major incidents are this paper's focus as they generally involve external assistance (Schmocker, Cooper et al. 2005). This may include diverting commuters to other operating lines or bus bridging (Boyd, Maier et al. 1998). Bus bridging involves establishing short-term bus routes to restore connectivity between disrupted stations (Kepaptsoglou and Karlaftis 2009).

Research on the effects of transit service disruption is limited (Balog, Boyd et al. 2003). Work done by Kepaptsoglou and Karlaftis (2009; 2010), Codina and Marin (2010) and Schmocker et al. (2005) focussed on Metro systems and reviewed recovery strategies. Schmocker et al. (2005) and Pender et al. (In Press) noted the importance of crossovers on recovery strategies. Track crossovers enable trains to change tracks or turn back onto return tracks (Glover 2005). If a complete train is to pass from one track to another whilst moving, crossovers are essential (Esveld 2001). Similarly, few studies examine alternative ways of accommodating disrupted commuters (Kepaptsoglou and Karlaftis 2009). When a train operation is disturbed, passengers are forced to choose the best alternative. This task is not always easy given that information required for such decision-making is not always available (Tsuchiya, Sugiyama et al. 2006).

Janarthanan et al. (1984) stated that transit agencies should enter into agreements with bus companies to acquire the extra buses required during increased demand. Nearly thirty years later, rail agencies still rely on custom-made procedures containing limited suggestions in respect to substitute service establishment (Kepaptsoglou and Karlaftis 2009).

This paper will provide a review of current international industry practices to disruption management and in doing so consider a range of rail transit modes. Rail transit modes under consideration in this paper are defined in Table 1. This is based around the High-Performance Transit Mode Classification system according to Vuchic (2005).

Table 1 –Rail Transit Modes

Rail Transit Mode	Defining Criteria
Light Rail-Rapid Transit (LRT)	Modified LRT rolling stock operating on exclusive ROW. Such systems can be fully automated.
Rail-Rapid Transit (RT), Metro or Subway Network	Utilising high capacity electric trains with high acceleration and braking rates. It represents the highest-performance transit mode and can involve different support/guidance technology other than rail.
Suburban Rail (SR)	Railway lines running through the central city with many stations with electrical traction and operations with short headways (5-20 mins); they are very similar to RT networks.
Inter-City Rail (IR)	Railway lines operating from key regional cities which typically terminate in stub stations on city fringes and generally operate several inbound trains in the morning and outbound in the afternoon.
Country Rail (CR)	Railway lines operating from more remote towns, again typically terminating in stub stations on city fringes. They often consist of fewer than three trips daily each way and play a commuter/tourist role.

3. Methodology

3.1. Survey Aims

This paper uses a survey of industry practitioners to understand current industry practice in managing unplanned rail service disruptions. It contrasts approaches used by the different rail transit modes.

Planned disruptions were not considered given their occurrence is known in advance. Furthermore the research focussed on major incidents where the recovery time or additional 'slack' time in the timetable was not sufficient to allow for normal service resumption (Schmocker, Cooper et al. 2005).

3.2. Survey Approach – Semi-Structured Interview

A semi-structured interview approach was used as the basis of the survey. Participants from a total of 48 passenger rail transit agencies (representing 63 transit modes) were interviewed from Australasia, Europe, North America and South East Asia during the period of October 2011 to March 2012. Participants were selected with the assistance of associations such as the American Public Transport Association (APTA) and the International Association of Public Transport (UITP). Although ideally a larger sample would have been utilised, ultimately the authors were limited by funding, time, levels of interest, response rates and in some cases language barriers in non-English speaking countries. The participants were predominantly Rail Operations Managers. In some cases the interviews involved multiple participants, including those responsible for bus operations and customer service.

Semi-structured interviews were utilised given they are usually based upon prior participant observation (Silverman 1993). Denzin (1970) offered three reasons for this preference: they allow respondents to use their unique ways of defining the world, they assume that no fixed sequence of questions is suitable to all respondents and they allow respondents to raise important issues not contained in the schedule. Semi-structured interviews allow probing by the interviewer and interpretative validity, provide in-depth information and are useful for exploration and issue confirmation (Tashakkori and Teddlie 2003). Furthermore they "provide the best opportunity to find out what someone else thinks" (Bouma and Ling 2004, p.177). Finally the interview should also be flexible enough to allow the discussion to encompass relevant areas which may not have been considered prior to the interview (Goulding 2002).

3.3. Outline of Semi-Structured Interviews

The interview was structured according to eight categories:

1. Operating Environment;
2. Approaches to Unplanned Service Disruptions;
3. Causes of Unplanned Service Disruptions;
4. Impacts of Crossovers;
5. Utilising Rail Replacement Vehicles;
6. Designing Rail Replacement Routes;
7. Managing the Initial Unplanned Service Disruption; and
8. Challenges in Managing Unplanned Service Disruptions.

Table 2 – Passenger Rail Transit Agencies Surveyed (Australasia and Europe)

Operator	Location	Transit Mode					Operate bus	Min. 2 Track	Track Maint.	Temp. <0°
		LT	RT	SR	IR	CR				
Adelaide Metro	Adelaide			X			X		X	
Auckland Transport	Auckland			X						
CityRail	Sydney			X	X		X*		X#	
Citytrain	Brisbane			X	X				X	
CountryLink	N. S. Wales					X	X**			
GSR	Australia					X				
MetroTrains	Melbourne			X					X	
Transperth	Perth			X			X		X	
Transwa	W. Australia				X		X**			
Tranz Metro	Wellington			X	X				X#	
Tranz Scenic	N. Zealand					X			X#	
Traveltrain	Queensland					X				
V/Line	Victoria				X	X	X**		X	
BVG	Berlin		X				X	X	X	X
C2C	London			X						
East Midlands	London			X			X*	X^		
FCC	London			X			X	X^		
Greater Anglia	London			X						
Irish Rail	Ireland		X	X	X		X*	X^^	X	
London Overground	London			X			X*	X		
London Underground	London		X				X*	X		
Metropolitano de Lisboa	Lisbon		X					X	X	
NS	Netherlands				X	X				
RATP	Paris		X	X			X	X^^	X#	
STIB	Brussels		X				X	X		
Trenord	Lombardy			X	X					X
AMT	Montreal			X						X
Amtrak	USA				X	X				X
CTA	Chicago		X				X	X	X	X
GO Transit	Toronto			X			X			X
Long Island Rail Road	New York			X					X#	X
MARC	Maryland				X					X
MBTA	Boston	X	X	X			X	X^^	X	X
Metra	Chicago			X						X
Metro-North Railroad	New York			X					X#	X
New Jersey Transit	New Jersey			X			X			X
New York City Transit	New York City		X				X	X	X#	X
PATH	New York City		X					X		X
SEPTA	Pennsylvania	X	X	X			X	X^^	X	X
Staten Island Railway	New York City		X					X	X#	X
STM	Montreal		X				X	X	X	X
TTC	Toronto		X				X	X	X	X
VIA Rail	Canada				X	X				X
VRE	Virginia				X			X		X
WMATA	Washington DC		X				X	X	X	X
MRT Bangkok	Bangkok		X						X	
RapidKL LRT	Kuala Lumpur	X					X	X		
TRTC	Taipei		X					X^		

3.4. Survey Participants

Table 1 illustrates rail transit agencies who participated in the research and their operating region and city. They also illustrate network and environmental characteristics that impact on the management of unplanned disruptions and their likelihood of occurrence including:

- **Transit Mode** – Highlights the multiple transit modes operated by some transit agencies according to the classification system from Table 1;
- **Operate Bus** – Identifies rail agencies that also operate a route bus network;
- **Min. 2 Track** – Documents agencies that operate on a network that consists of a minimum of two-tracks i.e. no single track sections;
- **Track Maint.** – Illustrates agencies who are responsible for track maintenance as well as operations; and
- **Temp. <0°** – Notes the agencies that operate in an environment that can often have temperatures less than 0 degrees.

Please note the following keys to Table 1:

- X* – Buses operated by a sister/parent company;
- X** – Operates buses but not an option during disruptions;
- X^ - Less than five percent of the network is single track;
- X^ – RT network is completely double track; and
- X# – Parent company is responsible for track maintenance.
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4. Results

Given the vast amount of information collated during the interview process only the results of most relevance to the research objectives are documented accordingly:

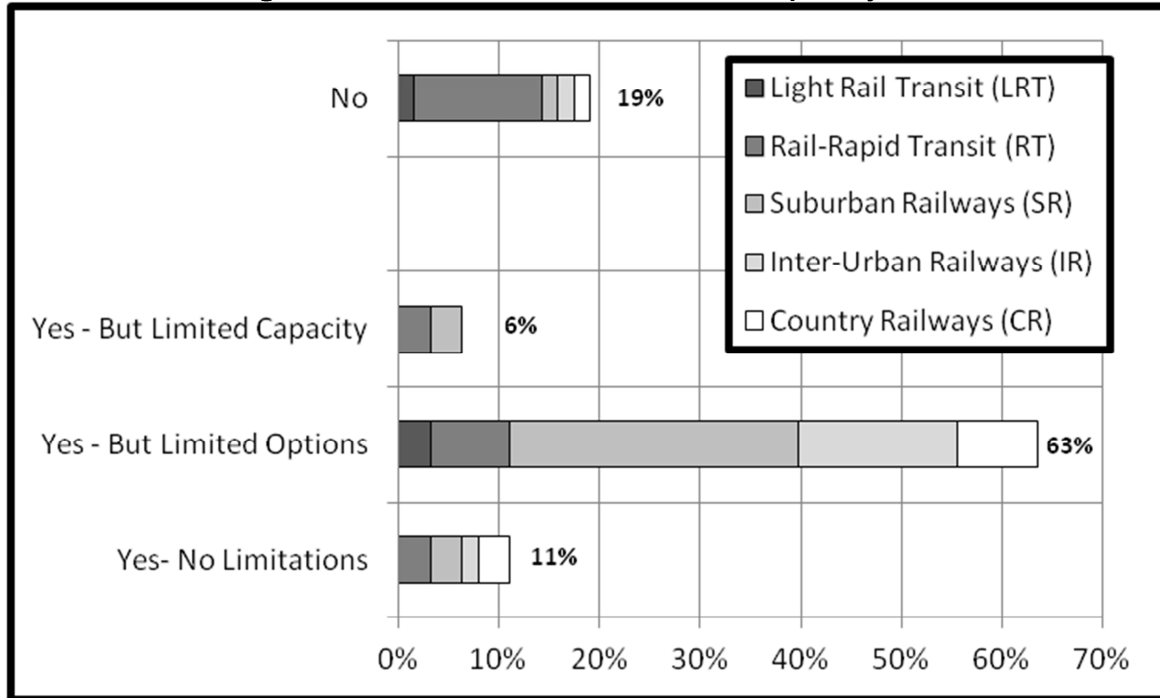
- Presence of Parallel Public Transport;
- Causes of Unplanned Service Disruptions;
- Approaches to Unplanned Service Disruptions;
- Impacts of Crossovers;
- Approaches to Utilising Rail-Replacement Buses; and
- Challenges in Managing Unplanned Service Disruptions.

4.1. Presence of Parallel Public Transport

The presence or absence of a parallel public transport network has a major influence on disruption management. This is because when a passenger rail corridor experiences a disruption that leads to part or the entire corridor being inoperable, one of the first alternatives is to make use of an existing or parallel public transport system that mirrors part or the entire corridor. Figure 1 highlights the feedback from the 48 rail transit agencies (63 rail transit modes) as to whether a parallel public transport system exists in their network.

As Figure 1 illustrates, most agencies believed there was a parallel public transport system in place, however, it often didn't mirror the entire rail corridor (63%) or if it did there would be capacity restraints (6%). Only a limited number of agencies (11%) believed that during disruptions their network had viable existing parallel public transport alternatives for commuters. Approximately double this number of agencies (19%) said that there was no such option in existence.

Figure 1 – Presence of Parallel Public Transport System



Most organisations said that feasible alternative systems were more prevalent in inner city areas, and as a result many RT agencies believed that the vast majority of trips done by commuters on their network could similarly be performed by existing bus routes. The London Underground and the CTA were two prime examples. However, as noted by New York City Transit, the parallel system was usually unable to cope with the additional demand, particularly during peak hours of operation.

Other agencies commented that their networks were designed so that the bus networks acted as feeder services and the costs associated with operating parallel or redundant public transport networks could not be justified. Interestingly in Montreal, the bus network was usually designed so that it replicated the RT network and was therefore the first option during extended periods of unplanned disruptions. Again, disruptions in peak periods meant that capacity could not always match demand.

In North American and European cities where the inner suburbs were serviced by a RT network and the outer suburbs by a SR network, often the two rail networks would mirror each other's network (to a certain extent) in the inner suburbs and downtown areas. Often this overlap would provide alternative public transport services when one network experienced a disruption. On the rail corridor between Newark, New Jersey and Manhattan, New York, PATH Transit and New Jersey Transit will direct their commuters to the alternative rail transit provider during periods of network disruptions. The commuters are not charged for their altered travel plans as there is a ticket recognition agreement in place.

Another example of parallel networks was on IR or CR networks operating between key cities and provincial towns. Given that in such cases, a highway network would often replicate the rail corridor, an existing bus service in operation between the same locations was quite common. Hours of operation of the bus service often meant that an alternative was not available during the initial stages of an unplanned service disruption. The Christchurch earthquakes in New Zealand in February 2011 was a prime example when Tranz Scenic initially provided rail replacement services but after the initial period, diverted commuters to existing parallel bus services.

4.2. Causes of Unplanned Service Disruptions

There are a number of occurrences that can result in an unplanned service disruption, however, these can be broadly categorised according to the following five categories:

- Intrusions/Medical Emergencies – includes suicides, track intrusions, railway crossing incidents and sick passengers;
- Weather/Natural Disasters – includes extremes of weather such as snow and heat waves and natural disasters such as earthquakes and cyclones;
- Track – includes all track-related issues including problems relating to power failures, signalling and crossovers;
- Other Trains – includes disruptions caused by other passenger trains or freight trains that share the network; and
- Rolling Stock – includes all rolling stock issues ranging from door obstructions to train failures.

Figure 2 – Causes of Unplanned Service Disruptions

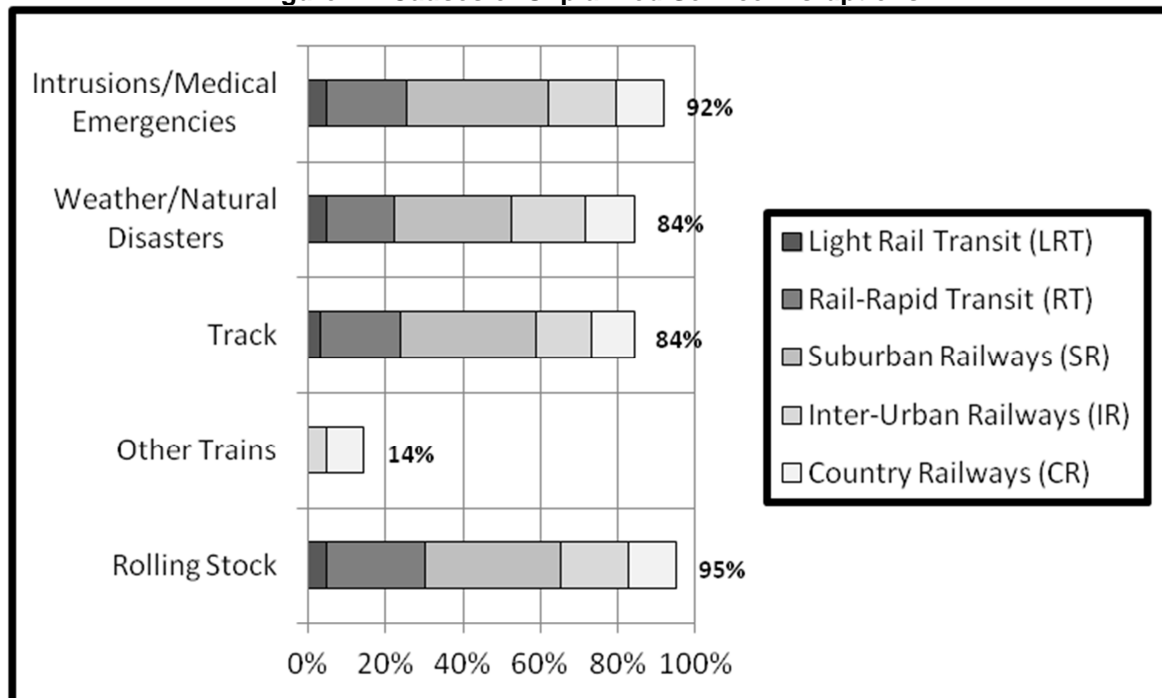


Figure 2 highlights the key causes of unplanned service disruptions identified during the survey. With the exceptions of disruptions caused by other trains all other causes were equally common although the likelihood of each cause varied according to transit mode, geography, network and rolling stock. Rolling stock and track problems are generally more likely to result in a service delay, whilst intrusions/medical emergencies and weather/natural disasters often result in a complete or partial line closure. The occurrence of suicides is quite prevalent and these often result in the longest delay before service resumption given the need for the police and coroners to be involved. Unfortunately they are often predictable according to the time of year as noted by FCC who stated, "suicides are linked to the various seasons."

Disruptions relating to weather or natural disasters can similarly result in long periods of delay before normal services resume. However, often after the initial disruption (i.e. the unplanned portion), the responses become more of a planned nature. The Metro-North Railroad in New York referred to their Port Jervis line given it was affected by Hurricane Irene in August 2011. It was three months before normal services resumed and during the interim rail-replacement bus services were provided.

4.3. Approaches to Unplanned Service Disruptions

The approaches to unplanned service disruptions varied according to whether there was a train failure or complete line blockage and the key approaches under either scenario are:

- Train Disabled:
 - Commuters to make use of alternative transport;
 - Altering train stopping patterns;
 - Transferring disrupted commuters to the next train;
 - Sacrificing operating lines to make rolling stock available to aid disruption;
 - Using spare locomotives or operating trains to move disrupted trains or 'gap trains' to provided additional service; and
 - Balancing out the frequency/headway of the remaining train service.
- Line Blockage:
 - Single tracking i.e. bypassing disrupted train/s or areas using crossovers;
 - Re-routing trains onto other operating train lines of the same network;
 - Diverting disrupted commuters to other operating lines;
 - Diverting disrupted commuters onto other parallel public transport services;
 - Improving frequencies of existing bus routes in the vicinity of the disruption;
 - Bus bridging;
 - Hiring taxis;
 - Chartering planes (option for CR networks); and
 - Suspending service and offering no alternatives to disrupted commuters.

Figure 3 – Approaches to Managing Unplanned Service Disruptions

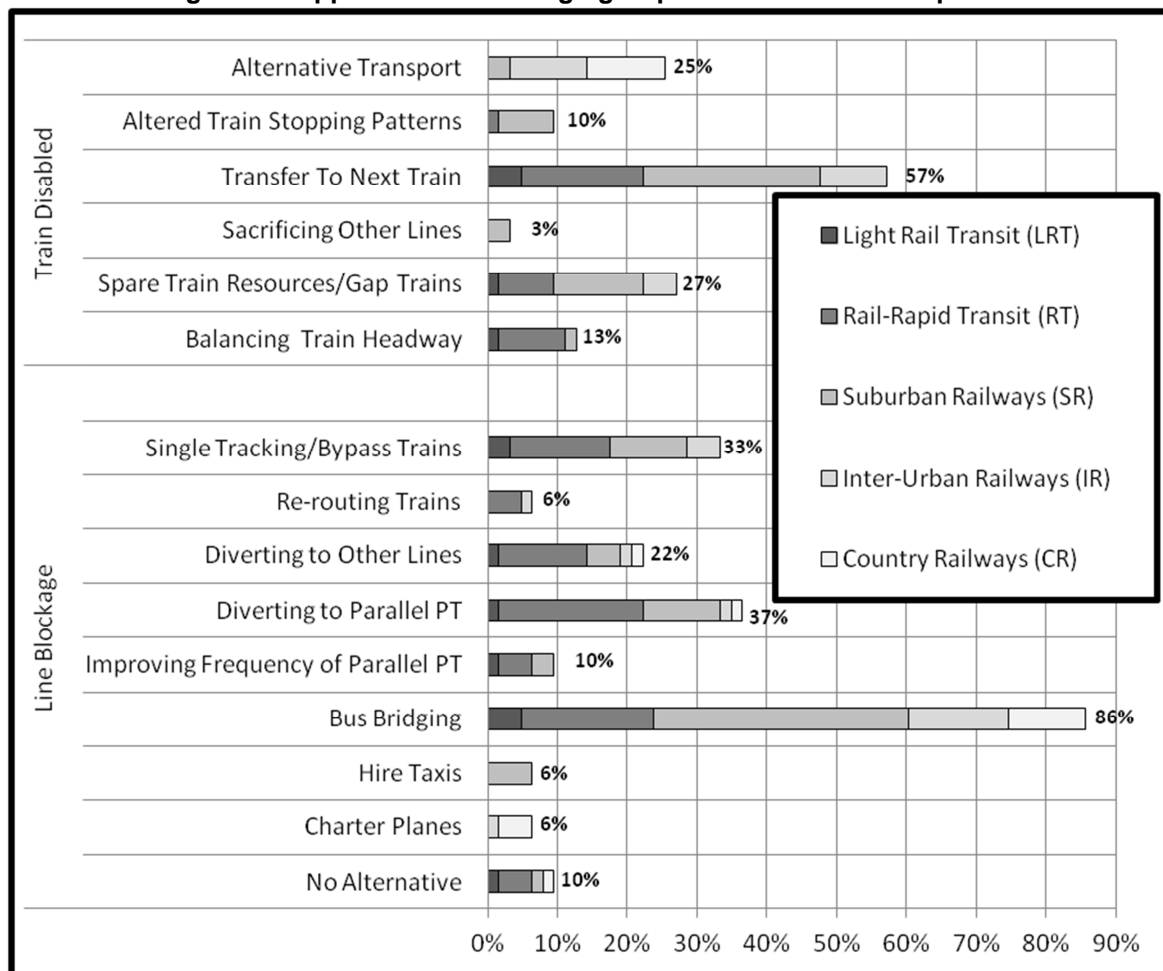


Figure 3 illustrates the dominance of bus bridging as a solution (86%) to deal with responses to unplanned service disruptions. However, it is worth noting that often agencies apply multiple approaches based on the time, location and type of the disruption. Rail networks surveyed in Australia and New Zealand viewed bus bridging as the main alternative. Similarly, the SR, IR and CR networks of Europe and North America showed greater preference to bus bridging but again its utilisation depended on the location, time, expected disruption duration period and the nature of the incident. These operators demonstrated a strong preference to 'bus bridge' to other operating lines. Metra noted, "to provide a replica service into downtown Chicago with buses would require significantly more resources than to provide a shuttle service to outer termini on the CTA network."

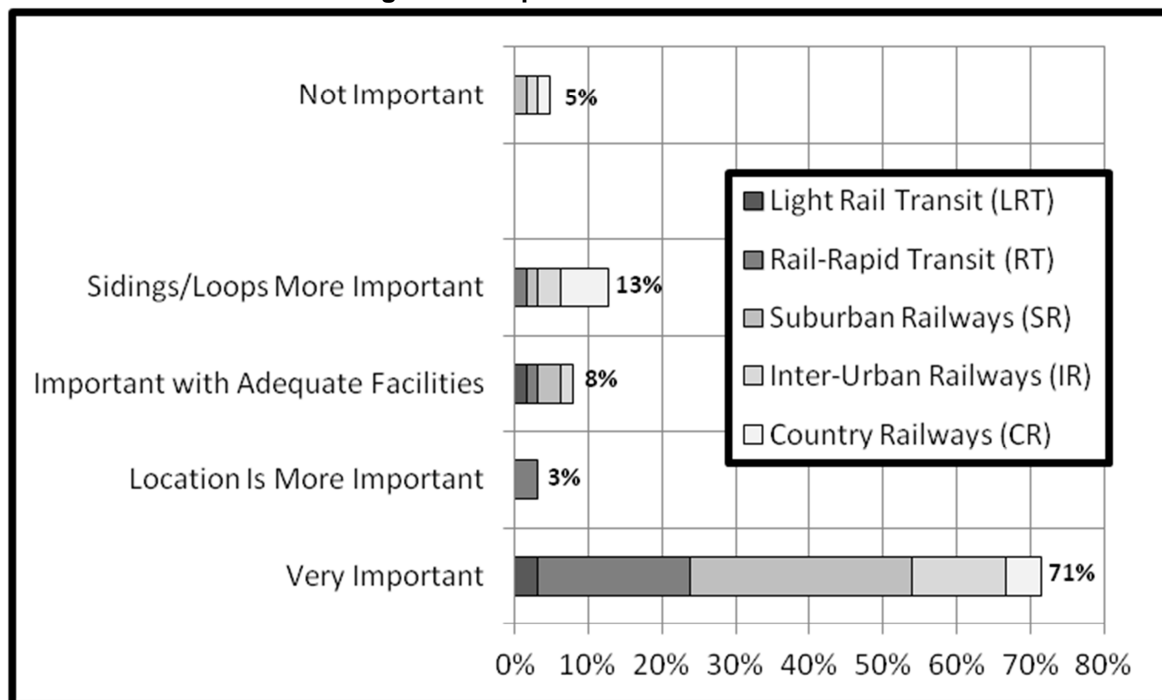
RT agencies such as the London Underground and SMT try to manage unplanned disruptions internally (i.e. without bus bridging) and on occasions where additional buses are required it is often to provide capacity on parallel bus routes. Similarly New York City Transit stated, "we really avoid buses, especially in emergencies. The fact is that we do not have the ability to get our hands on enough buses fast enough." PATH commented, "we will run on every portion of this railroad that we can during a disruption." Given the high service frequencies of many RT networks and that they operate to a published frequency band schedule, a common approach to deal with a disrupted train is to remove it from service and then balance out the frequency (termed 'flexing').

PATH Transit, TTC, WMATA and Metropolitano de Lisboa were all fortunate to have 'gap trains' that act as an automatic replacement for train failures. Greater Anglia, New Jersey Transit and Trenord have reserve locomotives, staffed with drivers, to move disrupted trains and therefore avoid the likelihood of further trains becoming disrupted.

4.4. Impacts of Crossovers

Figure 4 illustrates the vital role that crossovers play in service disruption management, with 71% of respondents identifying their importance.

Figure 4 – Importance of Crossovers



Long Island Rail Road commented, "I've never met a crossover I did not like." Similarly Adelaide Metro stated: "they are critical and you can never have enough of them", Auckland Transport: "they aid bi-directional running by allowing trains to bypass disrupted trains", whilst the CTA highlighted that crossovers allow you to minimise disruption effects. Operators of RT networks had a greater appreciation of crossovers given their importance in recovery techniques such as single-tracking and re-routing. In contrast, other operators found alternative infrastructure such as sidings and loops more important than crossovers.

Crossover provision is influenced by the balancing act that exists between the requirements of operations managers in responding to unplanned disruptions and the costs associated with maintenance. SEPTA's representative stated that "some of our lines have universal crossovers so that we can go from one track to the other. They are a control centre's dream, however, they are track department's nightmare because they have to maintain them."

In Australasia, agencies note the role that crossovers play regarding the design and implementation of rail replacement routes. The operators of CityRail stated, "they are key; we can only really start and terminate replacement routes at crossover locations." However, in contrast, Citytrain, commented, "but often they do not marry up with station infrastructure i.e. bus interchanges."

Figure 5 – Possibility of Crossovers Causing Disruptions

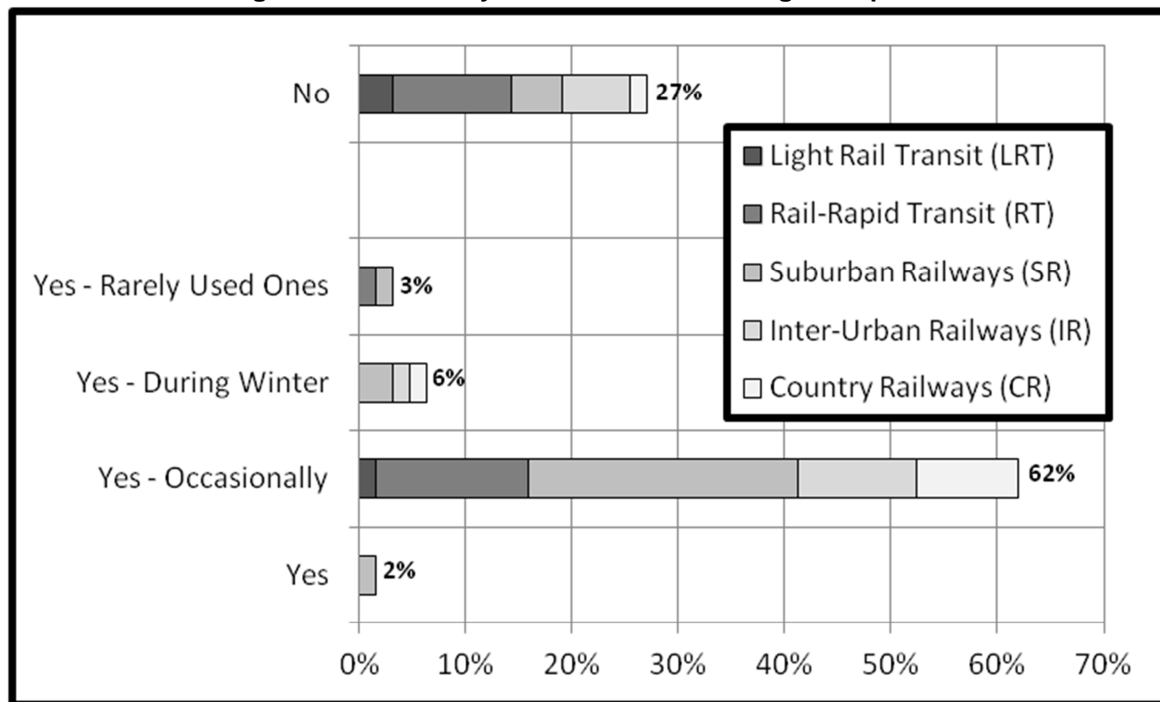


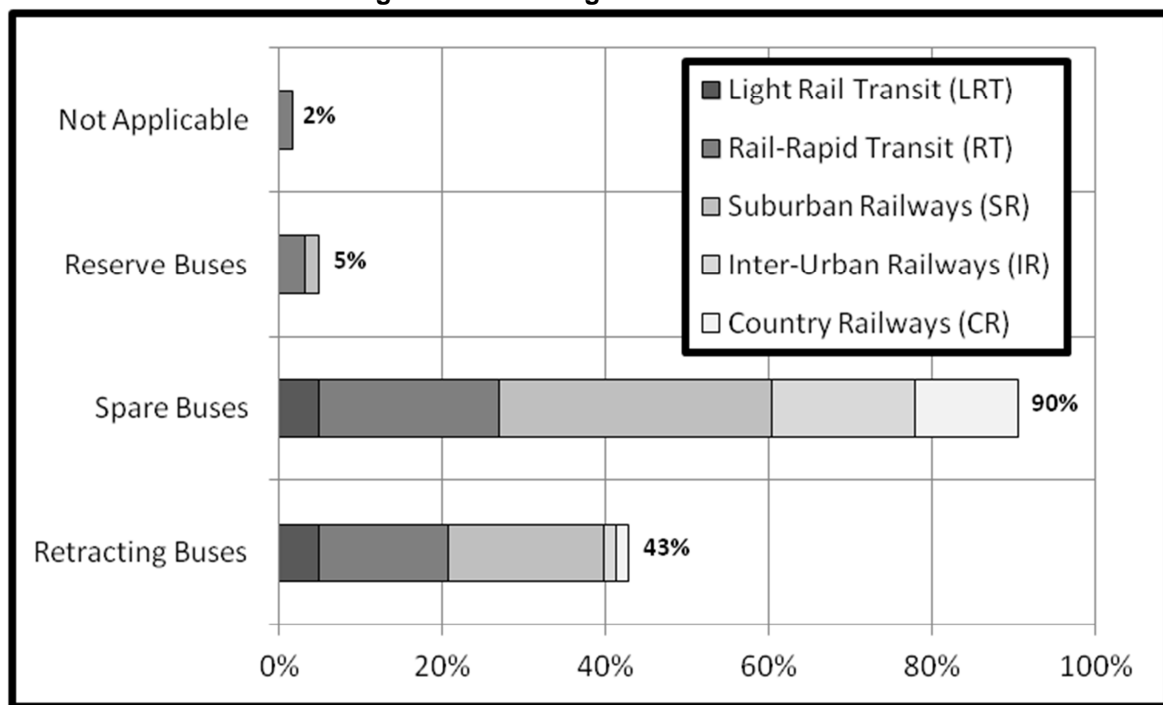
Figure 5 illustrates respondents' thoughts on whether crossovers actually caused unplanned service disruptions. A vast majority (62%) said they did, but only occasionally. In this respect STIB stated, "It's a fake argument. It's a question of maintenance." PATH surmised most agencies' thoughts: "the network flexibility provided by crossovers far outweighs their failures", Long Island Rail Road noted that with crossover failures, it only has to happen once and then there is a reluctance to use them again. London Underground added, "if you use crossovers that are infrequently used, invariably they might fail as well."

There was, however, great concern about crossover performance in snow and ice. GO Transit and Metra had problems with crossovers during high levels of snowfall and as a result investments have been made in heaters in the direct vicinity of crossovers. Similarly, NS have a resilience strategy where they close line sections in winter according to crossover location. This is a pro-active mitigation strategy which works well for most passengers. The NS rail track contractor Pro-Rail has a program to reduce rail crossovers because they cause disruptions, particularly in winter and is removing about 2,000; out of 7-8,000 nationally.

4.5. Approaches to Utilising Rail-Replacement Buses

Figure 6 highlights the different approaches to sourcing buses to supplement a disrupted train service. Reserve buses refer to buses purely kept for rail-replacement purposes, whilst spare buses are available buses not required for the normal bus operations. Retracting buses involves removing buses from normal scheduled service routes to replace the disrupted train service, whilst 'not applicable' referred to agencies that did not use rail-replacement buses. With the exception of the MRT Bangkok which does not employ bus bridging as a solution, all other agencies (90%) stated that they made use of spare buses. However, as previously noted, for some agencies, bus bridging is not always the first approach

Figure 6 – Sourcing Additional Buses



Buses being kept in reserve are rare, although there are some exceptions. WMATA keep 25 'strategic' buses to primarily support the bus operations. However, these are inevitably called upon to assist in rail service disruptions. Adelaide Metro, which is currently electrifying most of its network, have 70 buses purely set aside to replace train services during planned shutdowns which can also be employed for unplanned service disruptions. The main bus supplier to C2C has a core business as a bus dealer (i.e. selling/buying buses) and will have 25 to 30 buses available in both peak and off-peak periods.

Some organisations have 'reserve standards.' In this context reserve standard refers to supplying a given number of buses within a pre-defined period. STIB specifies that their bus division must provide two buses within 15 minutes of a service disruption. In Melbourne the arrangement is between MetroTrains and four private bus operators, specifying five buses within 30 minutes of a service disruption. As the operators of Metro North Railroad state, "when you design the contract the expectation is that the companies have X number of buses and they are available 24 hours a day, seven days a week. That's not necessarily the case. You just do the best with the resources you have."

Sourcing buses is most problematic in peak periods. Often the only option is to retract buses from existing routes with high service frequencies or in close proximity to the disruption. This is quite common with agencies responsible for both the train and bus networks, although as noted by the TTC, "you may in fact be simply shifting the problem or causing additional ones." GO Transit's bus network has certain trips defined as unscheduled extras. They are primarily back-up buses and are often used when buses are required.

Approaches to bus bridging route design are often influenced by the network and disruption characteristics. Transperth mentioned that every effort is made to ensure those travelling the furthest travel the quickest. MetroTrains, like a number of their international counterparts, will often bus commuters to adjacent operating lines. Metra make use of the CTA network (Chicago's RT or city and inner-suburban network) during disruptions by bussing disrupted commuters to their network. This reduces bus requirements due to the shorter distance and the reduced likelihood of traffic congestion.

Most organisations preferred to minimise rail-replacement bus journeys at the expense of increased transfers (i.e. train-bus-train versus train-longer bus) when replacing disrupted train services. RATP commented that maximising train usage was a priority to ensure bus requirements were minimised given it is impossible to fully replace the capacity of a disrupted train service, particularly in peak periods.

4.6. Challenges in Managing Unplanned Service Disruptions

Although a range of challenges were identified in the course of the interviews, the difficulty of effective communication was highlighted by most agencies. WMATA surmised most agencies' thoughts: "it is really understanding the situation and understanding what is going to happen." Similarly PATH commented, "it is the flow of your customers and getting information to them in a timely and accurate manner. We can move trains the way we need, it is just getting the right information to customers." As reinforced by the CTA, the most important element is, "communication, communication, communication."

Some agencies additionally noted the challenges associated with service resumption and recovery. Greater Anglia stated their key challenges as, "speed of response, being consistent and trying to get the network back to 'right time' as soon as possible", whilst RapidKL LRT highlighted that being able to resume service promptly and safely is often quite demanding. FCC also placed emphasis on the subsequent days of operation being potentially disrupted given trains may not be at the locations where required.

5. Discussion and Conclusions

This research paper explored approaches to service disruption management through an international interview process exploring how rail transit organisations plan for the unplanned. A total of 48 agencies representing 63 various rail transit modes participated. Mode type influenced both operating environment and service disruption approaches. LRT and RT networks, given their operating boundaries (i.e. inner city areas) noted that there were often existing parallel public transport networks that could be utilised during disruptions. These networks were more likely to use crossovers to bypass incidents or disrupted trains through single-tracking or by re-routing trains onto other lines. Alternatively, IR and CR networks demonstrated a stronger preference towards bus bridging but acknowledged that bus capacity could never fully satisfy the disrupted demand.

The vast majority of agencies highlighted the importance of crossovers and thought they were unlikely to cause disruptions; however, a number of agencies in colder climates commented on the increased likelihood of failure during heavy snowfall. Rolling stock problems and intrusions/medical emergencies were regarded as two of the four key causes of unplanned disruptions. The likelihood of each cause varied according to transit mode, geography, network and rolling stock.

Very few cities were fortunate enough to have buses purely in reserve to assist during unplanned incidents. In some networks there were gap trains located throughout the network as a first option, whilst other networks had reserve locomotives located strategically within the network to push/pull disrupted trains out of the way. However, in respect to sourcing additional buses for either bus bridging routes or to increase frequencies on existing parallel routes, retracting buses from existing routes was often a viable alternative. This tended to be common in cities where the rail transit agency was also responsible for a bus fleet. The delivery of information, both from the incident to the rail operator and from the rail operator to affected commuters, was one of the biggest challenges faced by rail operators. Some agencies highlighted issues associated with service resumption and recovery and the flow-on effects to future days of operation.

Although this international review was the first of its kind, there is still scope for further research. There is obviously the option to involve additional rail transit agencies but with further research it is hoped to be able to produce a pre-defined set of solutions for unplanned service disruptions responses accordingly. Ultimately any disruption can be categorised according to type, location, time and duration and it is hoped that the work done to date and further research in this field will provide passenger rail transit organisations with greater assistance in dealing with an often problematic area. Most organisations interviewed commented, "we think we do it well but we are never really sure." Unplanned disruptions by their very nature are unexpected events, however, as the outcomes of this research have highlighted preparations can be made to minimise their impacts. As one CTA representative commented, "if you fail to plan, you plan to fail."

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