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Improving bus bridging responses via satellite bus reserve locations

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ABSTRACT

This paper presents a new method for assessing satellite bus reserve location to best service unplanned rail service disruptions by optimising location in relation to travel time to rail replacement, the volume of rail replacement incidents and the scale and spatial distribution of passengers affected.

When rail disruptions unexpectedly occur, re-establishing network connectivity is paramount and the provision of bus bridging (or bus replacement service) is common. Minimising response times are critical in reducing impacts to affected commuters. Currently, reserve buses for such purposes are usually sourced from existing bus depot locations, which are generally situated to suit regular day to day operations. Strategically locating satellite bus reserves according to criteria such as disruption likelihood provides the opportunity to better cater for disrupted demand.

The method is presented and analysis highlights how ideal depot locations within the network changes as consideration is given to travel time to locations where bus bridging commences, likelihood of a disruption warranting bus bridging and commuter volumes affected. The paper discusses the implications of findings for future research and practice.

1. Introduction

Unplanned disruptions to railways can have significant impact on passengers and have become a critical issue for congested cities relying on rail for a high share of urban mobility (Dong et al., 2012). Current disruption management practice in passenger railways includes the option of mitigating impacts by establishing alternative transport including replacement bus services or bus bridging (Boyd et al., 1998; Kepaptsoglou and Karlaftis, 2010), however, this is subject to the availability of buses and bus response times (Kepaptsoglou and Karlaftis, 2009). Kepaptsoglou and Karlaftis (2009) suggest an important option for sourcing buses is reserve buses, however, no reference is made to bus depot location. Research focussing on regular bus operations acknowledges that optimally allocating buses to depots can yield operating savings (Kepaptsoglou et al., 2010). However, no research to date specifically addresses depot location in the context of bus bridging services.

One area of research, previously not considered in this context is location science which locates facilities subject to constraints, whilst minimising demand and costs (Hale and Moberg, 2003). Related research has focussed on reduced ambulance response times by optimising station locations (Andersson and Varbrand, 2007), a similar problem faced by rail agencies when looking to source bus bridging resources.

This paper presents a new method for assessing bus depot location to best respond to unplanned rail disruptions using bus bridging services. The aim is to explore the influence of travel time to locations where bus bridging commences, likelihood of a disruption requiring bus bridging, passenger volumes affected and the spatial distribution of demand on determining ideal depot locations for bus bridging resources.

In practice it is not practical to move urban bus depots to optimal locations for bus bridging because of cost limitations, the constrained availability of space for depots and that fact that they are usually located in relation to scheduled route bus services which represent the majority of their workload. This paper therefore considers a new concept in bus deployment; the satellite or virtual depot. This is a bus parking area where buses can be deployed as needed to respond to events such as a need for rail replacement bus services. Deployment of bus reserves in this way is unusual but has occurred for many ‘special event’ needs. This paper considers the question of where a reserve fleet should be located to better respond to bus bridging demands.

The paper commences with a literature review, followed by a description of the research methodology. Results are described and conclusions are presented including a summary of key findings and a discussion of their implications for future planning, practice and research.

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2. Research context

The rapid implementation of replacement services has been considered essential for the successful substitution of disrupted rail services with bus services or bus bridging (Kepaptsoglou and Karlaftis, 2009). The key objectives in such situations are (Kepaptsoglou and Karlaftis, 2010):

- Minimisation of travel times to stations where bus bridging services are initiated; and
- Minimisation of operational effects to the rest of the bus network.

Kepaptsoglou and Karlaftis (2009) suggest that rail replacement buses comprise either buses extracted from existing bus routes or reserve buses located at existing depots and present new approaches to planning extraction of buses from existing bus routes. However this research and related research by Codina and Marin (2010) do not consider how depot location for a bus bridging reserve might be optimised in relation to rail disruptions. In general it is widely acknowledge that bus depots are located in relation to the bulk of bus services rather than for more infrequent rail replacement duties.

An international survey of operational approaches to bus bridging suggested that extraction of buses from existing routes can often be problematic (Pender et al., 2013). For example Toronto Transit Commission, operators of Toronto's rail and bus networks noted, "you may in fact be simply shifting the problem or causing additional ones" Similarly Zeng et al. (2012), in exploring mitigation strategies for unplanned short-term tram disruptions, highlighted that the retraction of buses from regular service can interrupt bus schedules, cause passenger angst and often requires considerable time for the buses to arrive at the disruption site (Zeng et al., 2012). As a consequence they explore the use of taxis as an alternative including:

- Empty taxis awaiting jobs.
- Taxis that are close to existing passenger's destination; and
- Taxis with passengers that are in close proximity to the disrupted tram.

A bus reserve fleet might reasonably be considered as an alternative option, however, to date no research has considered where it might be best located in relation to rail disruptions. Such a location could be permanent i.e. a conventional bus depot or mobile such as a bus parking area or spare bus bays at a railway station interchange. For each approach a method to determine good location to park the reserve fleet would be required.

Location science research determines physical locations for a given set of facilities. The key objectives are commonly the minimisation of cost for satisfying a given set of demands subject to certain constraints. Such decisions are integral to a particular system's ability to satisfy its demands efficiently. Because these decisions can have lasting impacts, choices regarding the physical location of facilities will also affect the system's flexibility to meet evolving demands (Hale and Moberg, 2003).

Interest in location theory has developed strongly since the 1960s when Hakimi (1964) sought to locate police stations in a highway system. In an attempt to minimise the total distance between customers and their closest facility, Hakimi considered the issue of locating one or more facilities on a network. The most basic facility location problem formulations can be characterised as both static and deterministic. A number of researchers, have examined multi-objective extensions of these basic models (Owen and Daskin, 1998). Church and ReVelle (1976) measured the effectiveness of a facility location by determining the average distance travelled by those requiring access. As average travel distance increases (used interchangeably with travel time), facility accessibility and the location's effectiveness decrease. This is consistent for facilities such as emergency services like fire and ambulance services. In essence these problems are similar in nature to those associated with the bus bridging reserve fleet location problem. This is the focus of the research presented in this paper.

3. Research methodology

3.1. Conceptual problem

Fig. 1 presents the results of a conceptual analysis of the bus bridging problem in respect to the issue of bus reserve location. Five key elements that impact the process of optimally selecting depot locations for bus reserves are identified:

- Station attributes.
- Disruption attributes.
- Disruption likelihood.
- Travel time to disruption station.
- Volume and distribution of passengers affected.

For 'Station Attributes', bus bridging services inevitably commence at the locations of rail track crossovers which enable 'turn back' of trains (Pender et al., 2012). Bus replacement services start and end at these stations. Bus replacement services most typically are sent to terminus stations as soon as possible after disruptions occur. Logically reserve buses would be firstly sent to stations with the largest volume of disrupted passengers. These stations require appropriate facilities for informing and managing rail-to-bus transfer and staff to manage this.

'Disruption Attributes' are also important to designing bus bridging services. Shorter disruptions may not require bus bridging. Also for inner-city contexts, diverting passengers to parallel public transport systems is a valid alternative to operating a replacement bus bridging service (Pender et al., 2013).

The elements of 'Disruption Likelihood', 'Travel Time (Depot to Station)' and 'Commuters Affected (Magnitude)' are the major factors which act to determine where a reserve fleet might be located once stations and disruption factors are known. Clearly a service depot might best be located to minimise travel time, however, it also makes sense to target locations nearer stations that have a larger likelihood of a disruption. From another perspective a depot might best be located in areas of higher demand. These are the perspectives explored in this paper.

4. Analysis approach

This paper presents a new method for assessing bus reserve satellite depot locations to best respond to unplanned rail service disruptions. Specifically, the impact of travel time to locations where bus bridging commences, likelihood of a disruption requiring bus bridging and passenger volumes affected are explored. Analysis does not consider scale of bus fleet required, only satellite depot location, given the paper's focus is to demonstrate the impacts of location on response time. Consequently the size of the bus reserve is assumed fixed and that disrupted patronage demand is matched by available bus capacity.

A case study network is adopted for analysis; the metropolitan rail service in Melbourne (Australia). Melbourne's rail network is radial network of 15 train lines and 215 train stations assigned to four semi-autonomous rail 'groups' for rail-replacement purposes,