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Analysis of delays and delay mitigation on a metropolitan rail network using event based simulation

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A B S T R A C T

For a number of years, the quality of metro service provided by the Tyne and Wear Metro has been impacted by delayed services and non-punctual running. This study aims to look to combat these issues by first developing an event based simulation using Simu8 software, in order to analyse the current system's performance and its response to delays. A number of potential delay mitigation tactics are introduced and evaluated to assess their potential worth in mitigating delays that may arise within the system. They are then analysed using the simulation model that has been developed, and compared to a system with no delay mitigation tactics input. The potential benefits and the feasibility of such tactics are then evaluated, alongside an appraisal of the scale of delay that can reasonably be mitigated through the proposed tactics alone. It is hoped that the results presented show high enough potential to be considered as a future development to the metro, which could improve both delay response and overall punctuality, in turn increasing customer satisfaction with the network.

1. Introduction

1.1. Motivation

The Tyne and Wear Metro Network is the second largest, after London, metro system in the United Kingdom [28]. It first opened in phases in the early 1980's around Newcastle and North and South Tyneside. It was then expanded, firstly in 1991 with a line to Newcastle International Airport, followed by a 2002 extension to include Wearside [19]. It now provides 37 million journeys a year for passengers [12], with a daily ridership of over 100,000 people [16]. It is owned by Nexus, but since 2010 has been operated by DB Regio Tyne And Wear Limited, to a specification set by Nexus [10].

Nexus conduct reviews over 4 weeks periods appraising both metro punctuality and customer satisfaction of the service provided. These reviews identify a major issue with the system, namely the punctuality and reliability of service provided. It was found that for 2012/13, metro punctuality was just 86% with customer satisfaction of this punctuality being 76% over the same period [9].

There has been minimal independent review into delays and delay impact though, and remarkably little research into how the impact of these delay can be minimised. Furthermore, there is no literature that examines how information about delays is conveyed to passengers, or how an improvement in this provision of information could improve the quality of

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service received by passengers. This lack of communication with passengers during a delay situation has also been identified by a number of customers, who have raised their concerns at Nexus' 'Meet the Manager' sessions [17,18].

By analysing the impact, frequency and scope of delays, and attempting to mitigate them, a major obstacle to providing the optimum quality of service for the passenger could be removed.

1.2. Objectives

The first objective of this paper is to create a workable simulation of a section of metro network, which will allow the current performance of the system to be analysed. Then, possible delay mitigation strategies can also be analysed and evaluated using this simulation. Secondly, research into the frequency and types of delay that can reasonably be expected on the system, to identify delay scenarios that can be input into a simulation model to evaluate proposed mitigation tactics against.

This leads into the third objective of the study, to identify and test measures by which the impact of delays can be reduced, and investigate whether these could be practically applied on the Metro network. From this work, an analysis of the operational issues and constraints presented for any possible mitigation strategies is drawn, along with a comparison to how Nexus currently responds to delays on the system.

1.3. Methodology and paper organisation

Firstly, background research is conducted into metropolitan railway networks and railway delay mitigation in Section 2. Then, the categories of delay are identified, along with an appraisal of their prevalence on the Tyne & Wear Metro in Section 3. Section 4 initially identifies a suitable case study area of the network to examine, before presenting the rationale behind, and results for, an observation of the Metro. Section 5 builds on the findings from Section 4 to propose effective mitigation tactics for a variety of delay scenarios. Section 6 describes how the system can be realistically modelled using simulation software, before focusing explicitly on how to model the proposed mitigation tactics in Section 7. The results found from the various simulation set ups are presented in Section 8, with a detailed comparison between an unmitigated system, and the modelled mitigation tactics also shown here. Finally, Section 9 illustrates the conclusions drawn from the previous sections, including an evaluation of the simulation model and the mitigation tactics proposed, with potential future development work also identified.

2. Background & literature review

2.1. Mitigation of railway delays

The role of a rail network operator in responding to delays was described by Froloff as the process of returning a schedule that began in an optimal state, but was then delayed to induce a disrupted state, back closer to its original state through a series of corrective actions [7]. Carrel further expanded this sequence of corrective actions, or "interventions", with the operators first identifying a "target state" during disruptions, before taking measures such as holding trains, cancelling trains or diverting trains to achieve this target [3].

However, the ability to "intervene" and recover the situation depends on the scope and severity of the disruptions. A similar observation was made by Vromans and Kroon [29], who sought to tailor their simulation to small initial (primary) delays, and attempting to limit the knock-on, or "secondary", delays to other trains operating on the same line. The main distinction drawn was that between the unavoidable primary delays, from a scheduling standpoint, and the preventable secondary delays that the initial delays could cause. This leads to the desire for a delay mitigation strategy that both absorbs the primary delays quickly, and limits the number of secondary delays caused [29].

However the intention that this could be achieved in a real-time scenario, using live simulation has been doubted by many including Berger et al. [2] who commented that the lack of information about the disruptions, and that the time taken to collate them, then input them into a simulation would make this an unwieldy delay mitigation tactic [2]. Motraghi also reiterated the importance of the availability and accuracy of input data for simulation analysis, adding to the uncertainty that reliable disruption data could be counted upon in a real-time situation [15]. As such, Berger et al. alternatively suggested that instead, common delay patterns could be identified during simulation and experimentation [2]. The optimal response to these specific delay patterns could then be analysed to decide upon the best course of action to mitigate for the delays, then applied to future real-world situations.

The central motivation for Bender et al., and their delay management analysis of a single track, was to ascertain whether a train should wait for delayed passengers, or leave without them, therefore minimising delays for those already on the train [1]. This problem refers to the interconnection of different rail networks, not a major issue of the metro network, however the same principle applies to a metro car running ahead of schedule; should the train wait at a station to return to the prescribed timetable, akin to aiding the delayed passengers, or should the service instead proceed at usual operating speed, benefitting those already on the service.

Another delay simulation scenario applicable to the Tyne and Wear Metro case study is presented in the aforementioned Vromans paper. That of two homogenous timetables operating on the same section of line, as occurs in the sample metro