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An event based simulation model to evaluate the design of a rail interchange yard, which provides service to high speed and conventional railways

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ABSTRACT

Railway interchanges are key operational points on a railway. However, railways are changing due to rail networks being upgraded to include high speed lines. Therefore, to allow for the integration of high speed lines with current conventional railways there is a prevalent need for railway interchanges to be redesigned. The scope of this paper is to conduct a study to design a railway yard of the future, which will be able to facilitate an interchange between a high speed railway and a conventional railway. The design method implemented in this study is a progressive approach, which is based upon a simulation with subsequent evaluations and revisions. The final designs given in this study have been proven through evaluation to be a promising stream of rail research. The designs have also allowed for a discussion to be carried out on the economic benefits, which can be achieved for the United Kingdom's High Speed Two (HS2) project by utilising the railway interchanges designed in this study between the new high speed line and the current conventional rail network.

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1. Introduction

The motivation of this work is based on that throughout history the railway has proven to be a key contributing factor to the growth rate of a country due to the economic benefits which it provides [47]. In modern times, the positive contributing factor offered by railways can be seen to be increased by the introduction of a high speed railway [10]. However, high speed railways consequently present both new and increased challenges to the operations of a railway. These challenges are based upon data communication, tilt, speed control and human factors [34]. When a high speed train operates on a conventional track the train can exceed the maximum operational limits of the system presenting further challenges [5]. These challenges, which when not met and limits when exceeded, result in a tragedy such as the Santiago de Compostela derailment [6]. Therefore, it is integral for both maximum performance and safety that the system is controlled adequately.

The United Kingdom is currently one of the only remaining western countries which is not nationally connected by a high speed railway. However, this is set to change due to the passing of legislation which allows for a national high speed rail,

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HS2, to be built [19]. It is expected that the HS2 project will provide an economic benefit two times in magnitude of the cost which will be incurred to build it [20]. To achieve this economic benefit and for the railway to be successful, the operations of the railway must be carefully designed so that the system is optimised in terms of performance yet remains unequivocally safe.

The current plan for the HS2 Project is to purchase new rolling stock to run on the new system. Purchasing new rolling stock results in a large capital cost and as such it also does not utilise the maximum potential of the rolling stock which is available throughout the UK. The motivation of this work is to investigate what would have to be modified to allow conventional rolling stock to run on a high speed line, along with the time implication of these modifications. Through this investigation it will then become possible through the use of simulation software to design a railway interchange to accommodate an interchange between high speed and conventional railways, which will become increasingly more necessary in the future. Based upon the undertaken investigation and simulation it will then be possible to discuss the opportunity of delaying the purchase of dedicated high speed rolling stock for the HS2 project with the aim of achieving an economic saving.

The aim of this study is to design a railway interchange by means of a simulation to address the future commercial requirement of the railway industry for an interchange between a high speed railway and a conventional railway.

In order to develop a simulation model which is capable of fulfilling the needs of this study, it will be essential to advance current simulation methods which are utilised in train yard research. To achieve this advancement this study will draw on a number of different simulation design methods detailed and explained later in this paper, which will be used synchronously to develop a new design method. The new developed method will then be able to be applicable to future rail research allowing for more complex models to be simulated.

There are a number of steps which have to first be complete to allow for the objective of this work to be achieved. The first step is to define what operating criteria a train should be capable of to be classified as high speed. The next step is to investigate the operational differences between high speed trains and conventional trains, which will allow for knowledge of what modifications are required to allow for a conventional train to run on a high speed track. Based on the results of this investigation it will be possible to implement the design methodology of this study. The design methodology of this study is a progressive design approach utilising a decomposition simulation method. The first step of this methodology is to form an initial simulation design based on the operations which are required in the interchange to modify rolling stock. From this initial simulation design a variable is altered based on an output with the aim of improving the design. For the purposes of this study the output is the queue length at an operational point in a yard and the variable is the quantity of track at each operational point. The result of this process is a final design of an interchange yard. This design then allows for an investigatory discussion based on whether, utilising current conventional rolling stock will allow for the purchasing strategy of rolling stock as part of the HS2 project to be altered and delayed with the aim of producing an economic saving.

The expected outcome is a simulation model which represents a promising design for an interchange yard between a high speed railway and a conventional railway. A visual representation of the methodological approach of this study (incl. simulation concepts and methods) can be seen in Diagram 1.

As railways have become more prominent for both passenger and freight transport [9] the most effective utilisation of railways has become significantly more important. The importance of running an effective railway is that it allows for more cost effective schedules and operational systems to be used. Simulating a system to trial a new operating system or modification can be considered to be strategic, operational, or tactical [3]. The evaluation of the effectiveness of modifications on a system is carried out scientifically through the use of computer simulations. These simulations are typically based upon real systems and data, and as such they can be used to evaluate the predicted effects on performance of modifications to a system to investigate whether they should be implemented [28].

A simulation is based upon two keys components, nodes and lines. Nodes represent processes carried out as part of the system, whilst lines represent the possible directional movement capabilities between nodes. The method of reducing a complex system into simplified processes represented by both nodes and lines is a modelling process termed decomposition [28].

There is a wide range of simulation software available on the market which can be used, such as, Railsys, OpenTrack, SIMUL8 and Arena. The programming techniques which are used by each programme are different, although the user interface methods do have a similar scheme. Each programme works by having a system input block, which is based upon given parameters such as train arrival rates. The system input is then connected to blocks which are used to represent a process by routing arrows. The blocks which represent processes have parameters which are user defined and should be based upon investigated statistical data. Process blocks can either be an area where work is carried out, a server, or a storage area, a buffer [42]. The final part of the user interface is a system output block which removes a train from the simulation. The final similarity is that reports are given, which are specified by the user and show the output data of the simulation.

An important aspect when simulating a system is to use accurate parameters so that the overall simulation is accurate in replicating the real system [14]. In yard simulations these parameters come from processing times such as for a brake inspection, and their respective queuing times. Due to this queuing nature typically analytical queuing modelling theory is implemented when simulating a complex rail yard. Whereby, the arrival process, to the process of leaving can be viewed as one queue broken down into subsequent smaller queues for each process under the decomposition modelling approach (2009). [4] discusses a summation of different mathematical queuing methods such as exponential, Poisson and Erlang. Cooper [8] builds upon this by providing a more detailed explanation of queuing theory. However, the optimum method for model accuracy is to use real-world statistical data as suggest by Flier [14].

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