A High Speed Train Delay Inspection Performing Simulation-Based Optimization

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Abstract— **Delays and interruption undermines the efficiency and stability of rail network. The rescheduling of rail traffic requires means of managing operations before and after occurrences of sudden disruptions. In this paper, we have performed simulation followed by optimization for the given scenario based on temporary or partial breakdown due to electric malfunction of a high-speed train which planned to travel in HS2 line from London Old Oak Commons to Birmingham station. According to the scenario, the required variables such as maximum acceleration, emergency brake time, energy optimal deceleration, maximum travelling speed and total distance travelled by a train as been provided. Using these parameters, we have illustrated simulation-based optimization using linear programming. As a part of Simulation in the part 1, simulator has been created for a train travelling from London Old Oak Commons to Birmingham Interchange section of the high-speed line with distance between these two stations is 145km. The simulation is performed for a track with k signaling blocks and fixed train schedule. The constructed simulator is verified by introducing temporary break down for 30 minutes caused by electric malfunction. In part 2, Optimization has been performed using k and n parameters by creating a train schedule. We have showcased the train actual delays using the simulation performed part 1. Finally, we have validated the approach by considering the maximum number of trains operated under an average delay time.**

Keywords—Simulation, Optimization, blocks, signal, incident.

I. INTRODUCTION

In United Kingdom, the railway system serves a significant number of customers each day in a vast area of high reliable, speed and secure. Presently, the high-speed rail infrastructure of London is recognized as being one of the world's leading transportation networks for carrying vast volumes of traffic with efficient operation. The standard of service of the railway has gradually increased with the construction of a high-density railway system, the use of train consisting of multiple trains, high-frequency running, the distribution of tracks between rail services, the installation of stations and so on. Functioning at high-frequency cycles and exchanging of tracks among rail services, in specific, the main strategy of the London rail network to reduce the crowdedness of trains. The implementation of these measures has made a major contribution in making the United Kingdom's rail network more competitive and passenger friendly. Nevertheless, these measures have often created adverse consequences, involving (1) the regular frequency of delays and cancellations during peak hours, (2) the expansion of train delays to a broader core network, and (3) the period taken to unravel the disrupted rail schedule longer. Overcrowding and train delays, which happens every day, especially in the morning rush hour, have brought unbearable difficulty to passengers.

The United Kingdom's railway network runs at a capability close to its maximum. This leaves the network exposed to even mild glitches, which are causing major delays in the operation. Delay Stop time decreases due to the combination between high-frequency train service and residence time. Thus, in order to transport a million of passengers effectively with reduced capability, it is necessary not only to enhance specific services but also to take systematic and coordinated steps to deal with the entire rail network. A simulation system that investigates station passenger traffic and train function in a detailed way can aim to effectively explain the process and to find more successful measures to improve rail service. Accordingly, this study devised a simulation model for train operation, that replicates the conduct of train operation, considering the relationship between the trains. The length of the residence is associated with the increase of the abnormalities in the train. When using simulation model, this analysis attempted to replicate the condition of the service of the train under an actual delay [1].

II. PROBLEM STATEMENT AND LAYOUT

This paper demonstrates simulation-based optimization technique to be performed on a given scenario to simulate the interchange section of high-speed train on the basics of temporal breakdown of 30 mins due to malfunction and followed by optimization illustrating the actual delay time considering the part 1 simulation.

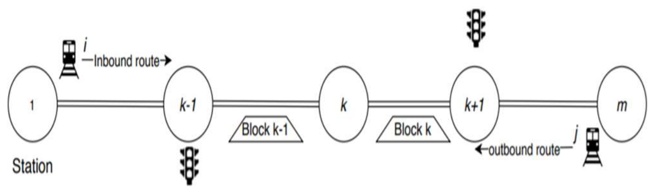

Fig. 1. The rail infrastructure

The rail network considered is shown in Figure 1. It comprises a set of stations (k = 1, 2, ..., m) and a set of running trains I = 1, 20, ..., n). The sections across each pair of stations called single blocks. We assume exact fixed block functions between stations where block parts start and end only at stations. Just one train is permitted to enter the track between two stations. During regular service, a train will travel from the present station if the next block section (signal) is open and there is at least one independent track portion in the next station. When a block segment stops, rail traffic is seriously interrupted. At this point, the key priority is to include a new model schedule for all running trains at the end of the scheduling period so as to reduce the overall delay costs.

III. SIMULATION SYSTEM OF TRAIN TEMPORAL DELAY

In this section we have performed simulation for high-speed train travelling from London Old Oak Commons to Birmingham. The total distance covered by train between these two stations is 145km. As per the assumption given the track consisting of k signaling blocks of equal length and fixed train schedule of n trains per hour is considered.

The simulator has been performed using the given required variables such as, maximum acceleration of $0.76 m/s^2$, train can brake in an emergency at $2.5\ m/s^2$ and deceleration of optimal energy is $0.38 m/s^2$. The maximum train speed is 310km/h (86.1m/s). In this given scenario impact of air resistance is ignored by considering constant acceleration until maximum speed. The train takes about 113.3s to accelerate from 0 to maximum speed by covering about 4878mts.

At first stage, using colab environment all the necessary packages have been imported including numpy, pandas, simpy for simulation. Separate function blocks have been defined for calculating the important inputs for simulation including, blocks location, maximum time at top speed of the train, deceleration time, mathematical formulations have been used to derive train acceleration time. The structure_data() function is declared to calculate the time taken to decelerate and accelerate during the block signal switch which is been set to 2 minutes using init function. The network class have been initialized incorporating trace and line() functions. Whereas, using trace() function we have calculated the start and end time using parse time function. line() function is declared to handle the unexpected and temporal delays due to malfunctions. The train() class is constructed to track down the complete train movement with exact time taken from the start point for a train until it reaches the destination. Using the line1() function the train start time is captured which is starting at London Old Oak station. Similarly, the we have declared a function block to track down the trains entry and exist time of every signal blocks which lies at an equal distance. The function has been declared by setting constant 10 minutes time interval for consecutive train movements. Using the above defined objects full simulation has been performed by simulating trains starting form London Old Oak commons for every consecutive 6 minutes.

A. *Simulator Verification*

Based on the simulation done for a high-speed train travelling from London Old Oak Commons to Birmingham Interchange considering the track with k signaling blocks of equal length and fixed train schedule time per hour. We have verified the simulation run by introducing a temporary breakdown due to electric malfunction occurred in 9 am train travelling from London to Birmingham. It is been is stated that it takes approximately 30 mins to fix the problem. On verifying the simulator output, the trace function was used to trace down the entire simulation run of trains started from 7 am to 10 pm. With the use of line() function which is used to handle the sudden malfunction. It has been successfully verified that the execution has been paused for the trains after the 9 am train and resumes successfully right after 30 minutes of recovery time.

IV. OPTIMIZATION

As per the analytical argument, we need to refine the simulation model to examine the optimal train speed per hour so that the total delay period is not more than half the scheduled time. For this function, the Ordinary least square (OLS) regression is initially used to analyze the dependence of the average delay period on objective variables such as trains per hour and signal blocks. From the regression analysis, it should be observed that the model 's output is measured by the modified r2 value of 0.915, which means that the model's accuracy is 91.5 per cent. We then use the Monte-Carlo algorithm to reduce travel time and maximize the speed of the trains. We then use the Monte-Carlo algorithm to reduce travel time and maximize the speed of trains. This is one of a wide range of optimization models that focus on repetitive random simulations to produce numerical results. The number of bricks is labeled x with a range of 4 to 11, and the number of trains is labeled y with a range of 6 to 10. From the optimization analysis, it is decided that a maximum of 10 trains running concurrently after 6 minutes each would be the best optimized solution for the target with 7 signal blocks of equivalent length.

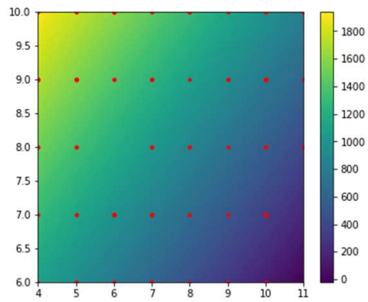

Fig 2, Monte carlo output

V. CONCLUSION

In this paper, we have conducted simulation-based optimization for the given scenario of high-speed train which travel in HS2 line from London Old Oak Commons to Birmingham. As a part of first section, simulation has been executed considering all the given variables of the train. On verifying the executed simulation according to the temporal break down due to electric malfunction in 9 am train, it has been successful to see the train delay of 30 mins for trains after 9 am. As a part of second stage, optimization has been performed to report the actual delay time. From the OLS regression result the obtained, the model outperformed by producing a result of 91% accuracy. By using monte carlo optimization method, recursive variable simulation has generated an optimum result of 10 trains starting consecutively in a 6 minutes interval with rail track of 7 signal blocks of equal length.

REFERENCES

[1] M. Shakibayifar, A. Sheikholeslami and F. Corman, "A simulation-based optimization approach to reschedule train traffic in uncertain conditions during disruptions", Scientia Iranica, vol. 25, no. 0, pp. 646-662, 2017. Available: 10.24200/sci.2017.4186.