JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ANALYSIS OF RAILWAY TIMETABLING AND ROUTING USING OPERATIONS RESEARCH: A SYSTEMATIC REVIEW

[1]Parv Jain, [2]Nidhi Bhat, [3]Nityam Bafna, [4]Nyasa Sachwani, [5]Nysa Luthra

[1]Research Student, [2]Research Student, [3]Research Student, [4]Research Student, [5]Research Student
Anil Surendra Modi School of Commerce, NMIMS, Mumbai, India

Abstract :

Purpose- Railways have been the backbone of the transportation industry for the past few centuries and have advanced a lot in the past few decades, so managing them is quite a mammoth task. This topic of analyzing railway timetabling and routing has been researched a lot. This systematic review paper aims at reviewing different research papers published and analyzed different models used in the papers.

Design/methodology/approach- The research paper is conducted in stages where different papers are reviewed under the literature review section and then later on have been analyzed upon with citation networks and data graphs.

Originality/value- This bibliometric research paper includes the most updated work on the analysis of railway timetables and routing using Operations Research.

Paper type- Literature review

Keywords: Operations, Research, Railway, Timetabling, Routing, Scheduling, Optimization, Planning, Problem, Models, Disruptions, Constraints, Delay, Rerouting, Double-Line Tracks, Micro, Macro

I. INTRODUCTION

Railway system is organized by an intricate network of infrastructure, human capital and other complex resources. Since people's demand for mobility and therefore increasing number of trains grows at a faster pace than creation of new railway structures, the railway network becomes heavily concentrated which leads to disruptions and adverse implications. Railway scheduling is done through time-tabling, specifying accurate service timings which may include delays and buffers due to negligence, breakdown, weather, maintenance, congestion etc. The relevant solution suggested for set-back of railway schedules is adding buffer periods and increasing the planned-stretch for running to absorb minor alterations to the timetable wherein trains change routes, platforms and tracks, quickly adapting without stalling other vehicles. Rail planning process comprises of complicate processes such as train time tabling, rail line planning, rolling stock and crew scheduling. It is essential to design and optimize models for each of these to achieve various goals such as minimizing total completion time of transportation, achieving lowest possible operation cost, achieving maximum passenger satisfaction, evaluating the optimal train schedule.

although there is a fixed capacity on trains, the number of passengers can be changed by proper schedule. This can be strategically formulated by analyzing factors like schedule of passengers, their arrival time, destination, seating arrangement helps us to evaluate solutions for ideal results and profit. Usually, the main goal of transportation problems is to minimize the total transportation completion time. The "line planning problem (LPP) and train timetabling problem (TTP)" are two basic and closely related issues in railway systems that are included in the strategic and tactical levels.

In cases of disruptions the pre existing models need to be modified based on the arrived scenario.

Literature on disruption management is more scarce than literature on train rescheduling and delay management (see for instance Corman, D'Ariano, Pacciarelli,& Pranzo (2009) and Dollevoet, Huisman, Schmidt, & Schöbel(2012)for models that deal with small timetable deviations) Rail scheduling and maintenance actions are activities of conflicting nature because higher number of vehicles are required to fulfill its objectives of mobility while dealing with various disruptions and constraints ensuring timely service and security of passengers and goods loaded whereas maintenance is necessary to ensure optimum utilization of railway infrastructure and network so as to keep it in a prime state. Therefore, designing and arrangement of timetables and schedules is primary at functional and calculated levels. The organization of rail congestion is solved through a "Train Timetabling Problem (TTP)" comprising of all aspects of arrival, departure, waiting time, distance between two stations, time spent at stations and other services. But the time-frame for certain characteristics like maintenance cannot be predetermined and are unspecified at the planning phase which therefore requires a different approach of Tactical Traffic and Possession Scheduling Problem (TTPSP) (D'Ariano et al., 2019), which is concerned with re-sequencing, rescheduling and changing routes accordingly

when some information is acquired. It focuses on optimum and feasible time-tabling to increase time and cost utilization (Zhi, 2019).

The presented paper helps us to understand the various contributions by the respected authors which gave a much broader view of how timetabling occurs in a railway network. It is formed by a cluster of routes which when combined together enable a proper functioning of the railways.(Dick, n.d.-a) However, there are possibilities of various disruptions and errors happening. With the help of various methods and models proposed by various researchers, it is an effort made through this paper to understand the various prospects of timetabling, scheduling, rerouting and so on.(Dunkin et al., 2009a)

II. LITERATURE REVIEW:

This section reviews articles on different mathematical formulations, models, experiments, software applied to the topic of paper.

(Polinder et al., 2021) deals with a new approach to periodic timetabling with linearing of a mixed integer quadratic program "Strategic Passenger-Oriented Timetabling" which includes waiting time at stations in objective function and provides synchronization patterns between different networks for optimality for passengers. Although, the method was not able to examine the “sensitivity” of demand rate, it provides feasible strategic timetables under various assumptions.

(Barrena et al., 2014) studies rail time table using mathematical models and experiments considering changing demand based on flow variables (linear representation of objective function), branch and cut algorithm (linear relative to non-convex and non-monotonic objective function). The model was successful in reducing the average waiting period for passengers after scrutinizing departure and rail speed elements.

(Q. Zhang et al., 2020) describes a method for simultaneous re-scheduling of platforms, re-routing of tracks and solving train timetabling problems at tactical level by applying a time-capacity system on a microscale level called “0-1 binary integer programming model”. The two approaches of dynamic programming used are “Lagrangian Relaxation” and “Alternating Direction Method of Multipliers (ADMM)”. The paper suggests a flexible track application policy and was successful in using ADMM for optimum infrastructure usage and reducing rail cancellations. Similar model approach has been suggested in (Cacchiani et al., 2012)

(Corman & Henken, 2022a) uses the concept of "capacity" and density flow speed and network fundamental diagrams to analyze the impact of railway traffic based on quantitative and qualitative tools of delay analysis, principle component analysis queueing theory and simulations for railway operations pivoting around delay and other complex heterogeneous railway services and resources planning. It utilizes the model of Microscopic Fundamental Diagram which did not support concrete and existent dynamics, necessary for assessment of level of performance and cost-utility. MFD assumes that people select other alternatives as an ideal choice based on their requirement.

(D’Ariano et al., 2019), (Petering et al., 2016) focuses on railway congestion and routing scheduling using mathematical models of mixed integer linear programming model and Pareto-optimal solutions under various constraints to fulfil objectives in distinct stochastic environments to minimize deviations to ensure consistency, rationality, and feasibility. The bi-objective problems were conducted on practical networks for trains and infrastructures competing for resources to balance and satisfy the conflicting interests of rail services and maintenance to provide primary, quality solutions. It collates traffic and maintenance for maximum optimality and cost-benefit. The routing consistency was found to reduce flexibility and suggests development of problem- focused algorithms and models that assists in relevant decision making based on traffic and maintenance flow.

(Pätzold & Schöbel, 2016) A matching heuristic and algorithm to solve a narrowed form of Periodic Event Scheduling Problem with constraints for optimized rail arrangement. Although the method ignored certain constraints due to complexity, The use of Modulo Simplex aided improvement in assignment and sequencing of tracks. (Cordone & Redaelli, 2011; Sun et al., 2014)

(Jensen et al., 2020) based on maximising capacity of rail services considering long term arrangement and heterogeneity of the functioning. It tests the feasibility and optimality of the problem after examining several constraints using two methods: Exact branch-and-bound algorithm and Tabu search heuristic which helped in analyzing substantial information on framework and various plots for stronger adoption of changes in infrastructure, rolling stock that increases cost-benefit analysis

(L. Kroon et al., n.d.-a) Deals with mixed integer linear programming algorithms of “Periodic Event Scheduling Problem”, “Designer of network schedules” for cyclical and robust timetables for platform assignment, feasible and optimal route selection. software “CPLEX 9.0”, “Simulation model for networks” helped in punctuality, cross-train planning, complex data assessment.

(Albrecht et al., 2013) Proposed “Problem Space Search (PSS)” meta-heuristic Based on “Schedulemiser” software provides a broad number of permutations and combinations of track scheduling and maintenance simultaneously. Given the time- benefit of dealing with complex data, the manual labor force can be used for better interpretation and analysis of resulting alternatives for quicker re-arrangement and altering due to delays or disruptions.

(Jafarian-Moghaddam, 2021) focuses on a genetic algorithm “sustainable elastic train scheduling” on a three-objective model and use of Lingo software. It identifies the elasticity of speed, length, weight capacity of trains and cost of operations as a trade-off to increasing revenues from operations, providing better safety, punctuality, and energy efficiency to help in optimal rail development.

(H. Pan et al., 2022) proposes the simultaneous integration of rolling stock circulation and rail flexibility using column-based diving heuristic algorithms. The model was tested on several existent (varied depot) scenarios. Solver was used for complex constraints; it provided schedules for lowering cost. The paper would further extend its research with improvement to implement the model in a stochastic environment.

(Gao & Niu, 2021) focuses on heterogeneity of trains to ensure flexibility and adhering to complex constraints (congestion, limited availability) under "Alternating direction method of multipliers (ADMM)" as an arc-based zero-one integer programming pattern. The priority based ADMM was found to be pertinent for dense data inputs.

(Ning et al., 2022) uses a bi-objective MILP model to develop an optimized synchronized timetable (last train) that made it possible for maximum number of passengers to reach their preferred (or closest to) destination. The further research would concentrate on making feasible schedules in a dynamic demand environment. Similar study is undertaken in (K. Huang et al., 2021), (S. Zhan et al., 2015)

(Y. Zhang, Guo, et al., 2022) is based on the optimisation of routes, schedules, safety, costs of Railway out-of-gauge freight (ROF) using mathematical models like Simpack simulation software. Other tools like safety simulation model, double checking approach and multimodal transportation model are used to gauge important parameters like safety gap, road dependability, tunnels, weight capacity. The method proposed by the paper.calculated various constraints, developed objective function, built an optimal model and selected routes based on ranking. The conclusion of the approach contributed to providing tactical and functional results that aid in meeting the target and decision-making process for the railway out-of-gauge freight transportation. (Setyawan & Diah Damayanti, 2018; Veelenturf et al., 2014)

(Reynolds & Maher, 2022)The research conducted in UK, concentrates on formulations of different speed profiles wherein trains need to accelerate or deaccelerate in order to accustom to the re-arrangement of the network to allow smooth functioning of other rails based on Train Timetable Rescheduling Problem (TTRP) and simulation approach. The further research would include comparison of speed models and find "disguised time".

(Yin et al., 2017) focuses on employing technological advancements into railways in the form of Automatic Train Operation, as a way of increasing efficiency in terms of speed, time, cost, infrastructure by reducing manual workforce intensive practices through the advent of digitalization and development of new communication interface. It addresses the contemporary rail operations and drawbacks through optimizing speed profile, traffic control and train speed controller relating to ATO as an alternative that is environment friendly, reliable and optimizes services.

(Y. Wang & Li, 2022) developed a new approach to "Train Platforming and Routing" with space-time modeling. Through numerical formulation, experiments and sensitivity analysis, it explores three interlocking modes: "route-locking route-release (RLRR)", "route-locking sectional-release (RLSR)" and "sectional-locking sectional-release (SLSR)". RLSR proved to be constructive for dense rail-operations lacking technological advancements and SLSR for optimal decision making and scheduling for individual terminals.

(Zhou et al., 2022) describes a real-time disruption management approach. It discusses the rescheduling of the rolling stock and the timetable. It focuses on the changed passenger demand. The timetable decisions are limited to additional stops of trains at stations at which they normally would not call. It discusses the adptations to the timetable while noting the estimated effects. It proposes a disruption management approach to integrate rescheduling of rolling stock and the adaptation of stopping patterns. This helps in improving passenger service.

(Chen et al., 2020)This paper focuses on the high speed railway location, which is one of the highest in hierarchy, for example, Beijing, Shijiazhuang, Wuhan high-speed railway station, etc. in China, and try to optimize its timetable. It focuses on analysing the problem and suggests strategies to adjust time and platforms for transfer scheme.

(Fuchs et al., 2022)This paper provides a domain model and problem formulation that is able to take advantage of the available infrastructure by allowing train itinerary allocation during timetabling. It focuses on 2 main modules, the LPP module and the TTP module. He talks about the need to achieve more efficient and integrated public transport planning. It proposes an iterative approach based on an improved feedback loop between two tasks, LPP and TTP.

(Lee et al., 2016) It talks about resolving the delays in railway timetables. This can be done by extending the dwell time for the busy hour train services in some frequently crowded stations in the timetable.In this study, a railway delay root cause explanatory model is presented to integrate heterogeneous railway operation data sources, which can effectively reconstruct the details of the railway operations, and a supervised decision following machine learning and data mining techniques is designed to estimate the key factors in knock-on delays.

(Hassannayebi et al., 2019)The passenger wait time under random disturbances is proposed to be minimised in this research using a meta-model simulation-based optimization approach. The modelling framework is built on a mix of response surface methodology (RSM) and discrete event simulation, hence combining the advantages of both approaches. An analysis of variance (ANOVA) test and the computation of second-order derivatives are used to conduct the verification procedure. The suggested meta-model simulation-optimization method can be expanded in future study to create energy-efficient train schedules. Through hybrid SBO, it is also useful to estimate additional parameters, such as the resilience and reliability of the train timetable.

(Martin-Iradi & Ropke, 2022) based on “dive-and-cut-and-price procedure” and “Benders’ cuts" which uses symmetric tables, columns (representing train paths) and graph conceptualization considering dynamic and concrete constraints for optimal consolidated routing schedules for commuters. Denmark and New Zealand are areas of assessment. In conclusion, the integration of Bender’s cuts was not useful in the model as it requires upgraded consolidation. Other rail elements can be added for analysis but the model would become complicated given the dense railway network.

(Gong et al., 2021) studied an integer nonlinear constraints programming model based on VNS Approach for collaborative optimisation of timetables in a dynamic environment which was later modified into ”equivalent integer linear programming” based on CPLEX. The study was able to provide energy-efficient speed schedules, relevant to practical real-life implications.

(Y. Xu et al., 2020) Proposes a “energy efficient train control” timetable optimization complication using a “nonlinear mixed integer programming” model which is then modified into space-time-speed network (STS) and segment level trajectory approach and algorithm. The conclusion of the model resulted in time and energy efficiency for interval, arrival, departure and cost calculations.

(Rangaraj, 2005) Talks about the need of cyclic timetables and the characteristics of public, operating and cyclic timetables. It is observed that A “frequency-based” timetable is useful for waiting period for users and cost efficiency. The paper further discussed the constraints-based techniques followed by optimisation procedures of forming a cyclic (frequency based) time table and the practical difficulties in doing the same. Examples of cyclic timetables in the Indian Railways were discussed.

(L. Kroon et al., 2009) focuses on cyclic classification of timetables in which the PESP is formulated through feasibility finding using CADANS: constraints programming approach and DONS: Designer of network schedules and SIMONE: simulated model for networks. The paper suggests building new infrastructure in accordance with the formulated timetable for higher running capacity which requires enormous funding. (Kümmling et al., 2015; Zhong et al., 2013) also propose similar model.

(Kumar, 2001) focuses on solving the three most important issues faced by Indian Railway

1. Locomotive assignment problem

The objective of reduction of operating costs and reduction of fleet size was achieved using “problem decomposition”

2. Optimal designs of timetables

Dynamic and static timetables were formed using Integer Programming solved by Langrangian relaxation. Techniques like Simulated Annealing and Genetic algorithms can also be used for small networks.

3. Dynamic Prices of servicing

The question of how high the tariff prices can go, (keeping the demand curve and airplane prices in mind) has been answered using predictive analytics (Harrod, 2012a) presents four fundamental timetable formulations suitable for optimization.(MISLP, BIOP, hypergraph, and PESP)

MISLP (oldest approach) is appropriate for real valued scheduling of single period schedules. But is limited to pairwise train dispatching decisions, reducing the feasible solution set.

“BIOP” is suited for the combinatorial packing of train paths within a complex network.

“THE HYPERGRAPH” deals with limitations in BIOP.

PESP is the only timetabling model in regular service. It is suited for the solutions with many interrelated passenger connections between trains.

The 2005 timetable of the Berlin subway (based on the results of mathematical programming techniquue is the first service concept which has been put into daily operations. The work is based on a well-built graph model (“the periodic event-scheduling problem”), which was introduced in 1989. The success story of this model is described in (Liebchen,2008)

(M. Wang et al., 2019) In this study, a mixed integer programming model is proposed to address timetable rescheduling problems. The model considers timetable rescheduling strategies like retiming, reordering, and adjusting stop pattern. A “genetic algorithm-based particle swarm optimization algorithm” is developed. Moreover, a numerical experiment of Beijing-Shanghai high-speed railway corridor is implemented to test the proposed model and algorithm. (Caimi et al., 2017a; Zhu et al., 2017)

(S. Zhao et al., 2021) methods to optimize line planning for high-speed railway network with time-varying demand. A “bi-level programming model” based on “Stackelberg game theory” was constructed, to obtain time information. The model is solved “by a decomposition searching strategy”. A case study on a partial HSR network is also discussed

(Huisman et al., 2005) gives an overview of state-of-the-art Operations Research models and techniques used in passenger railway transportation. For each planning phase (strategic, tactical and operational), the problems are discussed. These methods are then used to solve problems at the largest Dutch railway operator, NS Reizigers.

(J. Hartleb & Schmidt, 2022) proposed a novel timetabling approach with integrated passenger distribution model. Two MILPs: one integrates a linear distribution, the other simulates the distribution, along with a comparison of the models in experiments to state-of-the-art timetabling methods. The effect of multiple/single route and integrated/predetermined routing was shown. Integrating a passenger distribution model can help to find better timetables.

It was observed that different evaluation functions yield different results for the considered methods. However, it raises the question of whether this function is suitable for evaluation when multiple paths are involved.

(Zhu & Goverde, 2021) shows a multiple-disruption timetable rescheduling model for multiple complete track blockages that are pairwise connected by at least one train line using 2 approaches- sequential approach and combined approach (Both tested on real life instances in on a subnetwork of Dutch railways). High quality solutions for multiple disruptions were developed using the "rolling horizon solution method". We can conclude that the combined approach is able to handle more kinds of multiple disruption scenarios and generate better solutions as compared to the sequential approach. However, this model has not been tested for larger railway networks

(Lamorgese & Mannino, 2015) a real-time train dispatching problem is discussed. Here they show how to decompose the problem into smaller subproblems which forming the basis for a "master-slave solution algorithm" (master problem= line and slave problem= stations). Extensive tests on double-track lines in Italy were conducted. It was observed that this method showed significant improvement in minimizing overall delay as compared to the classical methods. This exact approach has been incorporated in the railway operations in Norway since February 2014.

(Odijk, 1996) solves the problem of constructing periodic timetables using a mathematical model consisting of periodic time window constraints by means of

which arrival and departure times can be related pairwise on a clock, rather than on a linear time axis. This is an extension of the PESP model. Furthermore, A new algorithm based on constraints generation is used to work out a real-life example (solve the PESP). Towards the end, a non-trivial example to demonstrate the timetable structure model has been worked out. It is observed that This method can be used to not only construct railway timetables effectively, but also to investigate the feasibility or make revisions in the current timetables.

(Liebchen et al., 2010) This paper provides a computational study which aims at computing delay resistant periodic timetables keeping delay management objective. This is an extension of the concept of "light robustness"

This technique was applied to the German railway. This model was successful in decreasing passenger delays at small price of robustness.

(Hansen, 2006) This paper uses analytical techniques and microsimulation to maximize capacity in stochastic train operations. Combinatorial models and max-plus algebra techniques are helpful for network timetable optimization and stability analysis, analytical (queueing) models and microsimulation are utilized to estimate waiting times. Using conditional probability distributions of delays caused by headway restrictions and route conflicts, a probabilistic model for the estimation of delay propagation is explored. Stochastic timetable optimization will help in the development of efficient distribution of running time margins and increased punctuality in large networks.

(Y. Oh et al., 2020) This paper develops dwell time estimation models for a Shinbundang line (S line) in Seoul, South Korea using support vector regression (SVR), multiple linear regression (MLR), and random forest (RF) techniques utilizing archived real-time metro operation data along with smart card-based passenger information.

(R. L. Burdett & Kozan, 2010) This study focused on the representation and creation of precise railway schedules using a "hybrid job shop method". As a result of this research, a novel strategy for resolving job shop challenges with capacitated buffers was suggested. Unique elements of train scheduling such were included into the "job shop scheduling framework" and, more specifically, into an inventive "AON disjunctive graph" representation. The core algorithm uses insertion, backtracking, and advanced dynamic route selection methods to build a schedule operation by operation and job by work. Thus, guaranteeing a feasible solution. Good quality solutions approaching optimality can be quickly obtained via this method.

(L. Kroon et al., 2008) The "time supplements and buffer" periods of a particular timetable can be distributed using the "stochastic optimization model" to make the timetable as robust as possible to stochastic disturbances. NS Reizigers, was used to test the stochastic optimization model. Additionally, a timetable based on this model was followed on the so-called "Zaanlijn." The findings demonstrate that by making very minor adjustments to a particular timetable, the average delays of trains can decrease dramatically.

(J. S. M. Hartleb, 2022) This paper focuses on efficient solution strategies for proper preparation of railway timetables for providing better services to the passengers. It discusses the availability of various optimization approaches for timetabling and the various assumptions which are made in order to provide the best quality to the recipients. Two ways are discussed which helped to integrate the distribution of passengers on various routes along with the assumptions taken on single routes and distribution. The first assumption takes care of the fact that the shortest possible route is available for the passengers while the second emphasizes that the routes which are determined are self-sufficient in managing the passenger load in the network. there is the use of multiple evaluation functions for comparing the methods described in the paper. It highlights the integrated choice model which derives the passenger distribution system on different routes and also uses the artificial instances to compare with the regional methods.

(Z. Huang et al., 2022) This paper reviews the various prospects of timetabling in "high-speed railway (HSR) corridors" and also the time preferences which the passengers get to select the most suitable one to travel. It emphasizes two models namely, the operation-oriented model and the passenger centric model. Under the operation-oriented model, the operators try to maximize transport benefits by reducing the cost of operations and in the same premise, optimize the train travel time. (Verma & Pattanaik, 2015) It focuses on minimizing (Florian et al., 1976) the energy consumption and also uses the maxed-integer nonlinear optimization model for train rescheduling. The passenger centric model aims to comply with different needs of the passengers to

the sizeable extent which can be met. A timetable optimizer proposed by Khwanpruk helps to quickly generate a timetable which helps to meet the optimal options which can be offered at proper intervals.(Scheidt, n.d.)

(Q. L. R. M. P. X. Zhang, 2022) paper reviews two optimization problems which arise,i.e., "Train Timetabling Problem (TTP) and the Train Platforming Problem (TPP)" and formulates a 0-1 binary "integer programming model" which helps to minimize the operating costs of running the train. It emphasizes on "Maintenance Operation Tasks (MOTs)" which need to be done at regular intervals to ensure better capability. A Heuristic algorithm is also used to control the model and four strategies are determined to ensure a time interval between the trains.(Schüpbach et al., n.d.)

(Fuchs, 2022) This paper develops an understanding to overcome the 2 stages which include line planning and timetabling. It outlines a framework of better services which can be catered in the best feasible way in adherence to the existing framework.(Matière & Juin, 1973) The approaches used are Line Planning Program (LPP) and Timetabling Program (TTP) considering the routing and platforming program. It states that the existing approaches do not take into account the detailed infrastructure limitations while generating feedback.(Sevaux & le Quéré, 2003)

(L. Kroon et al., n.d.-b) This paper discusses the two aspects which suggest the interval between the arrival and departure of trains at different stations and halts. Also, it aims to determine the assignment of trains to adequate platforms on various routes. It uses mathematical optimization models for generating timetables such that there are minimal disturbances. It discusses the Periodic Event Scheduling Problem (PESP) developed by Serafini and Ukovich (1989) for generating the timetables. (Cordeau et al., 2001) However, it also discusses a drawback of cyclic timetables that they are not flexible and may prove to be inefficient.

(Almodóvar, 2013) In this, various cases are discussed in which emergencies arise due to different problems. One of them discussed is when the service line is hindered due to differences in demand and supply availability. It addresses the Vehicle Re-Scheduling Problem (VRSP) and uses an on-line optimization model to cater the same. This model is based on the simulation-based approach and agent-based approach. The simulation model uses algorithms to predict the schedules in the most optimal way while the agent-based approach uses Artificial Intelligence (AI) for decision making. (Vijay & Prasad, n.d.)

(S. J. Oh, 2021) This paper provides an insight to developing "an A/B skip-stop pattern (A/B SSP)" which helps in better transporting allocations and patterns usually in large areas because of various complications. It also states the demerit that the travel time usually increases while using this method. This paper tries to solve the problem using a model named LINGO. However, this method was found useful only for small distance routes.

(Zhuang et al., 2016b) This paper discusses the train delays due to significant reasons and the possibility of conflicts which may arise in operations and may also hinder the security on tracks. It elongates the various conflicts which are possible and also uses two evaluation indexes to cater the same. (Vorobyov et al., 2018) The first index evaluates the divergence of a single train while the other measures the possibility of happening using a computation method. This paper also announces a new prediction method which is considered to be more practical.

(Zhu & Goverde, 2019) uses a "Mixed Integer Linear Programming model" to introduce "flexible stopping and short turning" . It is also concerned with canceling, re-ordering the trains. Through this model, they want to ensure that each train is designated a platform at a given station and the entire process is completed with minimal or no delays.(Dick, n.d.-b) This model includes the realistic features depending on the infrastructure and is apt in terms of both the networks such as single-track lines as well as the double track lines.

(Binder, 2021) This paper focuses to provide utmost priority to the passengers for timetable rescheduling in case there is any disruption caused. A choice model is used and given to passengers wherein they can choose their travel plan in case there is any rescheduling. It searches for an optimum solution wherein there is minimal passenger delay as well as their needs are catered. A disposition timetable is prepared in accordance to the initial timetable with the modifications needed in the required areas.(Bussieck et al., 2004)

(Pascariu, 2021) This paper outlines the freight capacity of railways using the timetable approach. It uses a microscopic simulation to analyze the capacity of the freight node in accordance with the existing infrastructure and tries to bring an improvement in the approaches. This model is also used in a case study of Novara freight mode and the infrastructure is analyzed by using different timetable patterns looking for improvements, if possible.(Caprara et al., n.d.)

(Bešinović, 2019) In this paper, a model is proposed which aims to prepare a stable timetable which caters to the given demand at a particular point of time to maximize the demand fulfillment where there's a crunch in network capacity. The model minimizes the cycle time to search for the most feasible timetable for a particular railway track. Also, this model is also tested on the Dutch railways. It also suggests that a proper timetable would lead to a speed difference and would avoid delays.(Caimi et al., n.d.)

(Zhu & Goverde, 2020) offers alternative choices to passengers in case there are disruptions in the railway network. For this, they proposed a "Novel- passenger oriented timetable rescheduling model", which helped to reduce the mean time caused by the disruptions and next travel options. They have also developed an algorithm which is Adapted Fix-and-optimize (AFaO).(Dunkin et al., 2009b) This algorithm used in the model helped to shorten the time gaps.

(S. S. C. ,Shang, P. Q. J. S. M. Zhan, 2021) This paper talks about the internal and the external factors which may be responsible for a network disruption and hinder its operations. It involves the focus of the researchers towards effectively managing the delayed trains and the other trains on the route. Using the direction method of multipliers (ADMM), they devised strategies to manage the traffic and also displacing the passengers.(R. Burdett & Kozan, 2004)

(Herrigel, 2018) This paper aims to focus the growing requirements on service quality and to increase the utilization of the railway network. It also focused on Periodic Event Scheduling Problem (PESP), which helped to speed up time tables in an automatic mode. MILP is also used in the formulation of the time tables.(L. Kroon & Huisman, n.d.)

(Herrigel, 2018) This paper specifies the importance of tackling the problems of timetabling. It lays an emphasis on the train timetable and also includes job-shop scheduling, thus reducing the chances of delays occurring due to network traffic and disruptions caused on the route. Also, it determines the feasible running time between the halts. Some detailed practical factors are also taken into consideration in accordance to the timetable formation.

(Warg, 2016) This paper assesses the highly used railways railway network and proposes a method to evaluate the timetables whether they are capable of handling the traffic or not. It also takes into account the economic assessment. It also tests the historical data on delayed trains and compares the departure by the combination of common weights using different variables.

(S. W. S. C. L. S. M. Zhan, 2020) By using variable ticket pricing on trains, the authors of this research seek to create a railroad schedule that meets the needs of their passengers. To promote social justice, they sought to increase accessibility for low-income customers by adjusting ticket costs for trains running outside of peak times. To resolve this issue, they utilised a “mixed integer linear programming model”. They made sure that the railway company's revenue was not decreased while also lowering ticket prices for the majority of passengers. (Cohen et al., 2015)

(Parbo et al., 2016) This paper reviews about the railway when it comes to railway planning, there is a gap between ”passengers who look not only at the schedules but also at the entirety of their trip, from access to waiting to on-board travel and egress.” The reliability of railways timetables is an important factor. Passengers prioritize travel time higher, according to empirical data travel time reductions are less predictable because passengers associate an intrinsic disutility when estimating travel times. (Pender et al., 2013)This inefficiency could be broadly construed as a price in worry for having to contingency arrangements for disruptions, which could be viewed as the driving force behind the necessity for delay-resistant railroad schedules. the conclusions create a foundation for a more passenger-oriented railway timetabling ensuring that passengers are provided with the best service possible with the resources available.

(Goverde et al., 2016) This paper analyzes the performance-based railway timetabling which is integrated with the evaluation part. The evaluation is done on 3 levels. The levels are “microscopic, macroscopic, and corridor fine tuning level”. This is then checked whether the given analysis is optimal or not.

(Veelenturf et al., 2017) This paper discusses real-time disruption management, which involves changing the rolling stock and the timetable in order to account for the altered passenger demand. The operator may also increase the frequency of the trains that run to stations with increased demand. The only changes made to the timetable are additional train pauses at stations where they wouldn't ordinarily halt. So, a heuristic approach is used. We demonstrate the effectiveness of successive iterations of our algorithm using real-world examples from Netherlands Railways, the nation's main railroad operator.

(Caimi et al., 2017b) The project gives an outline of the current railway design in practice and the combinatorial models that were proposed for this application. The project puts emphasis on passenger railway services in the European railway market. It starts with an elucidation of the role of the time table to a railway system. It explains the different kind of subprocesses in time table design that need to be conducted.

(D. S. C. X. Chen, 2019) This paper talks about the draft train timetable (DTT) which helps to generate a rough plan of the timetable and the scheduled time at which trains run. This draft helps to improve the real time performance of the train operations as it tends to determine approximate time required along with the calculation of delays. It also uses algorithms to ascertain the arrival and departure time. This model was demonstrated in China with 11 stations and situation there improved approximately by 20% as compared to the original timetable.

(Dong, 2020) This article discusses about how to obtain a high-quality timetable and simultaneously consider more realistic conditions and an integrated combination optimization model of both train stop plans and timetables under time-dependent passenger demand. They used mixed-integer nonlinear programming problem (MINLP) to optimize passenger travel efficiency and An extended adaptive large-scale neighborhood search (ALNS) algorithm is made to solve the problem.

(F. Fuchs et al., 2021) This research paper discusses how railway infrastructure is important while constructing a timetabling problem. The method used in the research paper even identifies how small routing services can be used and instead of banning a whole railway plan, railway infrastructure can be efficiently used.

(Qi et al., 2018a) This paper aims at achieving railway optimization by using a model for timetabling, stop planning and evaluating passengers’ demand for origin and destination pairs on railway corridors. It is based on a more practical framework and helps in minimizing passengers’ travel time.

(Sparing & Goverde, 2017a) This study provides an optimal method to find a feasible railway timetable for diverse railway networks and to improve the optimization process, different reduction methods are also used. To prove the practicality, real-life case studies on Dutch railways are also analyzed.

(Xie et al., 2021)This research paper takes the real-life example of a high speed rail corridor in China and suggests that rail time schedules are quite important to establish safe conduct and timeliness of rail operations but considers train stop plans help in optimizing train timetabling and scheduling in such a way that is energy-saving and passenger oriented.

(X. Chen et al., 2022) This study aims at achieving optimization of timetables of passenger like container trains at road rail transport network and to achieve the integrated optimization, "a multi objective optimization model" is followed and also "a grid based algorithm" is used to solve the model. A case study of the China Europe transcontinental network is mentioned in the research paper to apply the model used.

(P. Wang & Goverde, 2019) Train trajectory optimization is used as a method to approach energy efficient train time scheduling. This method involves considering the arrival departure time pair as constraints in order to set the timetable. The approach further follows two methods, single train trajectory optimization(STTO) and multi train trajectory optimization(MTTO).

(Yan & Goverde, 2019) Railway networks have advanced quickly in recent years with the goal of reducing passenger travel times and meeting the rising passenger demand. Two critical problems at the strategic and tactical levels that form the basis of a high degree of service quality for railway operation are the "LPP(line planning problem) and TPP(train timetabling problem)". To solve this particular problem, a multi objective linear programming is used.

(Z. Liao et al., 2021) This research paper suggests that to solve capacity estimation problems, generally only infrastructure is taken into consideration but the research paper includes both infrastructure and vehicle resources to solve problems. A mixture of time and space network is used based on which a Lagrangian relaxation algorithm is used to solve the problem.

(L. Zhou et al., 2017) This study takes into account a "high-speed rail track" that needs precise scheduling of train networks for a sizable quantity of rail with both "limited power supply and limited time capacity". The goal of the study is to comprehensively combine issues with microscopic train trajectory calculations with macro train scheduling. The model used to solve the problem is a mixture of space, time and speed networks to describe various train trajectories.

(Cao et al., 2019) This paper is based on optimizing railway timetables by identifying departure times of a particular rail network. The model uses integer based programming problems and binary variables and is dealt with maximizing transfers at high speed rail networks. To test the model, computations were done on Beijing rail transit networks.

(Corman et al., 2014) In this paper, the potential application of an optimization-based paradigm for managing rail traffic congestion over a large network is radical assessed. Due to the severe traffic congestion, the Dutch railway network uses a practical application.

(Yan et al., 2019) an efficient and robust time schedule which effectively uses the railway infrastructure to the fullest. The e-constraint method is used and algorithms are used to create the pareto set ((S. Binder et al., 2017)

(*Copyright © 1997. All Rights Reserved.*, 1997)suggests an optimal approach for railway timetabling in such a way that it maximizes the profit while not violating the time and capacity constraints. The approach used in this paper to solve this problem is the Lagrangian relaxation approach and Swedish railways were used as a real life railway network to be tested on.

(Lamorgese et al., 2017)To meet future passenger inflow and demand, new rail infrastructures are planned and have to go through a trial and error process which involves formulating a new schedule and timetable which contemplates the demand and is undertaken in such a way that there is no unfeasible solution. In this paper an exact approach is taken to compute train timetables.

(Leutwiler & Corman, 2022)The important aspects of a rail network's proper operation is the planning of its timetables and rail schedules and it must maximize capacity for moving people and cargo and also adhering to all constraints at a microscopic scale. A logic Benders cut is created, which we can compute efficiently for all decomposed issues in the framework we are considering.

(Vansteenwegen & Oudheusden, 2006)The approach followed is build upon the Belgian rail system and late arrivals are devised and minimized in order to enhance passenger service. An ideal provision is created for delays to protect connections in an event when the train is running late. The paper also conducts standard linear programming and also optimizes the LP(linear programming) table.

(Canca & Zarzo, 2017) This research paper uses the model of MINLP(Mixed Integer Nonlinear optimization problem) for both origin destination pairs. Energy efficient timetables are designed as a result of speeds, dimensions, rolling stock of each railway line.

(Burggraeve & Vansteenwegen, 2017)The low capacity is one of the primary causes of delay propagation in virtually saturated station locations. This study suggests a technique for creating a cyclic timetable and a routing plan from scratch in order to maximize both passenger robustness and infrastructure occupancy.

(D. Wang et al., 2022)This study looks into a complex urban rail transit line's rolling stock scheduling issue of integrated deadhead routing and timetabling. To minimize the weighted sum of the total deadhead distance and total deadhead running time of rolling stocks, a new binary linear model is used via a time-space network representation.

(Högdahl et al., 2019) The essential characteristics of a rail conveyance service is its short travel time and high reliability. In order to capture these two crucial socio-economic features of a timetable, this study examines the challenge of creating a schedule for a given set of departures that minimizes the weighted total of scheduled travel time and estimated delay.

(X. Zhang & Nie, 2016) When compared to other optimization approaches for capacity evaluation, this method of timetable analysis can disclose different railway line designs and rules of operation that have a useful impact on enhancing capacity utilization. This paper includes various models like "(minimum cycle time calculation) MCTC model" and PESP train plan for macro scoping time scheduling and capacity analysis.

Other publications that encompass relevant aspects of our topic, includes " (Caset et al., 2019; Chierici et al., 2004; Ghoseiri et al., 2004; Goverde & Hansen, 2013; Hassannayebi et al., 2017; Lusby et al., 2011; *RAILWAY ROUTE OPTIMIZATION SYSTEM CASE STUDY: Kasese Railway Station*, n.d.; R. Wang et al., 2019; Y. Wang et al., 2021; Zwaneveld et al., 1996)"
"(Nemani et al., 2010) (Ke et al., 2015) (Ahuja et al., 2005; Bach et al., 2015; Budai, G., Huisman, D., & Dekker, 2006; R. L. Burdett & Kozan, 2009; Cacchiani et al., 2014; Cacchiani & Toth, 2012a; S. Chen et al., 2013; Dewilde et al., 2014; Engelhardt-Funke & Kolonko, 2004; He et al., 2000a; Içyüz-Ay et al., 2016; Ke et al., 2015; Kotsiopoulos, 1999; L. G. Kroon et al., 2014; Larsen et al., 2014; Lu et al., 2017; Nemani et al., 2010; Z. Pan et al., 2020; Qi et al., 2018b, 2021; Reisch et al., 2021; Sels et al., 2016; Van Aken et al., 2017; X. Xu et al., 2021; Yue et al., 2016; Y. Zhang, Peng, et al., 2022)"

III. RESEARCH METHODOLOGY:

IDENTIFY DATABASE AND KEYWORD SELECTION:

The literature curation of relevant material including research papers, articles, case studies, publications and reports was acquired from the following database and sources:

"Science Direct (https://www.sciencedirect.com/), Google Scholar (https://scholar.google.com/), EBSCO Host (https://www.ebsco.com/products/ebscohost-research-platform), JSTOR (https://www.jstor.org/), Sci-Hub.se (https://sci-hub.se/), ProQuest (https://www.proquest.com/), IEEE Xplore (https://ieeexplore.ieee.org/), IDEAS (https://ideas.repec.org/), Academia (https://www.academia.edu/), Springer (https://link.springer.com/), SAGE Journals (https://journals.sagepub.com/)"

The search strategy involved using following keywords in distinct combinations using logical operators ("AND", "OR") to identify a network and target publications to conduct the bibliometric analysis:

Group	Search Keywords
Railway planning related terms	Operations, Research, Railway, Timetabling, Routing, Scheduling, Optimization, Planning, Problem, Models, Disruptions, Constraints, Delay, Rerouting, Double-Line Tracks, Micro, Macro

ORGANIZATION AND CLASSIFICATION OF DATA:

In the initial literature search over 10,000 results were generated and on the selection of required article type, a dataset of 3148 results was assembled. After further deliberation, the data set was formulated into 250 papers. The research is narrowed to papers in "English" language to ensure equivalence and comparability between different years and no time period restrictions were applied.

The articles selected in the initial search were subject to a two-step screening process. In the primary tactic, the abstract, introduction, keywords and conclusion was given a thorough understanding to ensure validity and reliability. Therefore, segregating those articles that proved satisfactory and converged with the selection criteria were incorporated in the analysis technique. Reasons for excluding certain articles are:

a) Focused on the evolution of railway system
b Related to the pricing scheme and seating capacity
c) Extensively focused on the freight and goods transportation

In the second tactic, the selected articles were given an extensive study on their research methodology, analysis, applicability, findings.

The pertinent material was transferred to Mendeley Reference Manager which is used to insert citations and bibliography and systematic arrangement. At this stage, any identical articles were withdrawn. Further, the entire database from Mendeley was converted into Research Information Systems (*.ris) format with the objective of conducting Bibliometric Analysis employing software namely VosViewer, RStudio and Word Cloud.

The Selected material for research was therefore put in Vos Viewer to analyze the interlinkages between the various sets available. After putting forth the papers together, Vos Viewer generated a bubble shaped diagram which illustrated about the various methods used by the various authors. The size of the bubble depicted which of the methods were given priority and had the highest number of headcounts. The result produced was further used for the analysis among the data available.(Corman & Henken, 2022b; Z. J. L. H. Liao, 2022)

After the selection of material, the papers were segregated under four headings (“article name”, “publication year”, “authors”, “publication source”) in Microsoft Excel to construct visual representation consisting of graphs and tables.(Liu & Kozan, 2009)

BIBILOMETRIC ANALYSIS:

Analysis of publishing years:

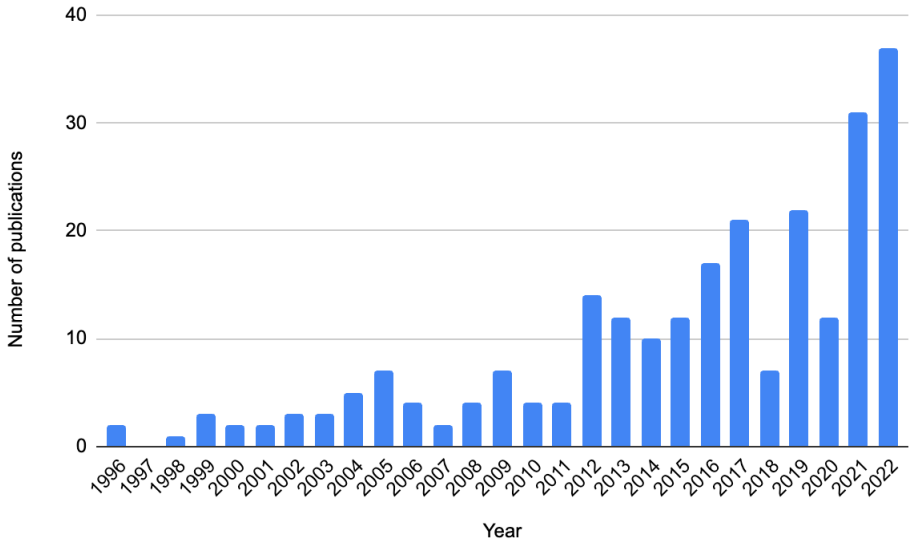

Figure 1 (Source: Google Sheet)

As per the bibliometric analysis using excel for the number of contributing papers within our time range (1996-2022), a maximum number of articles have been published in the year 2022 considering relevancy and major focus on the key aspects confined to our topic. A steady increase in aggregate number of researches can be identified on a year-on-year basis. Some reports and study done in the year of 2022 include (Alaghband & Moghaddam, 2022; Ding et al., 2022) . Publications saw the most substantial jump in the year 2021 with a focus on optimization, rescheduling and timetabling areas which includes the work of (K. Huang et al., 2021; Y. Wang et al., 2021)

Analysis of Publication Sources:

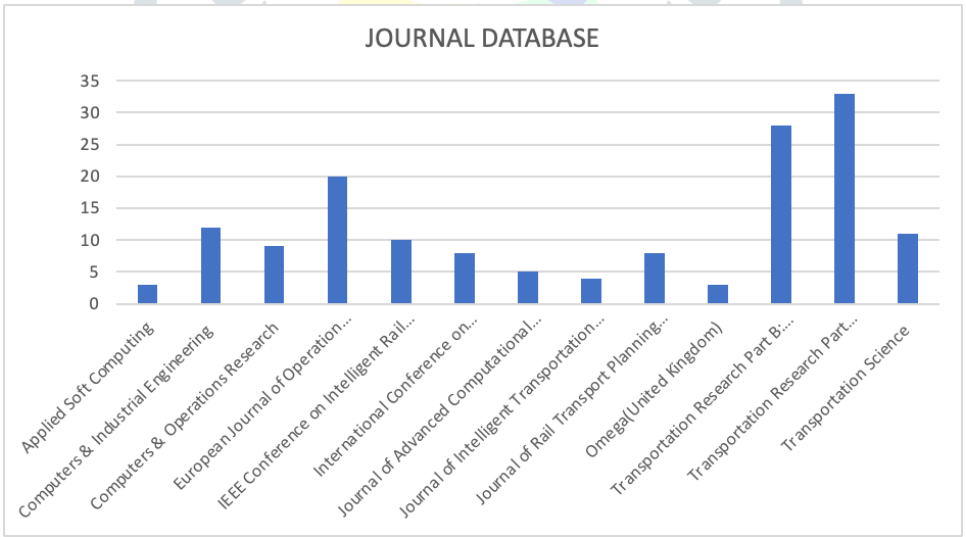

Figure 2 (Source: Google Sheet)

Figure 2 represents the number of articles published by different publications, various established journals were used to gather data in order to make it more relevant and compatible with the presented topic. These journals overlooked upon the topic and were considered to be the best suitable for research. The graph of the most famous journals has been formed to provide a better view of the conducted research. Among the given references, Transportation Research Part C: Emerging Technologies provided a major contribution for the research.(Shu et al., 2005; Törnquist, n.d.) It contained a chunk of papers which included various technologies being used to prepare timetables and rescheduling which gave a holistic view about the topic. The next in line was Transportation Research Part B: Methodological which described about the various methods in rerouting.(Srivastava et al., 2009)

Analysis of Co-Occurrence of Keywords:

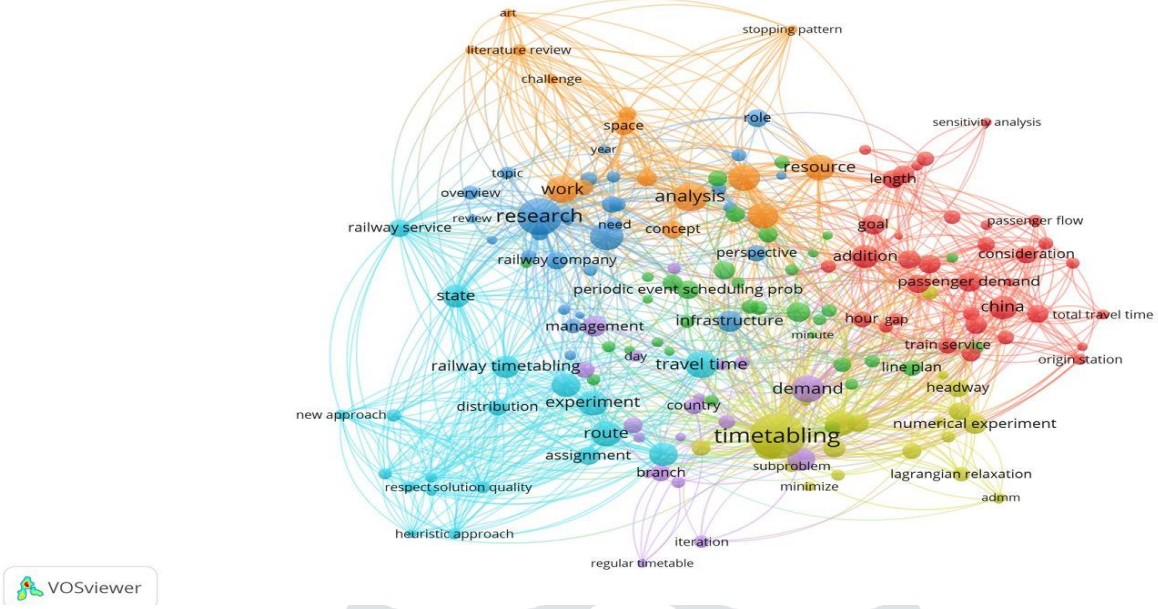

Figure 3

(Source: VOSviewer)

The network of keywords derived from the terms used in the contributing articles is shown in Figure 3. It is very clear that timetabling, analysis and research are the most used words in the research papers analyzed.

Analysis of Co-Occurrence of Title and Abstract Fields:

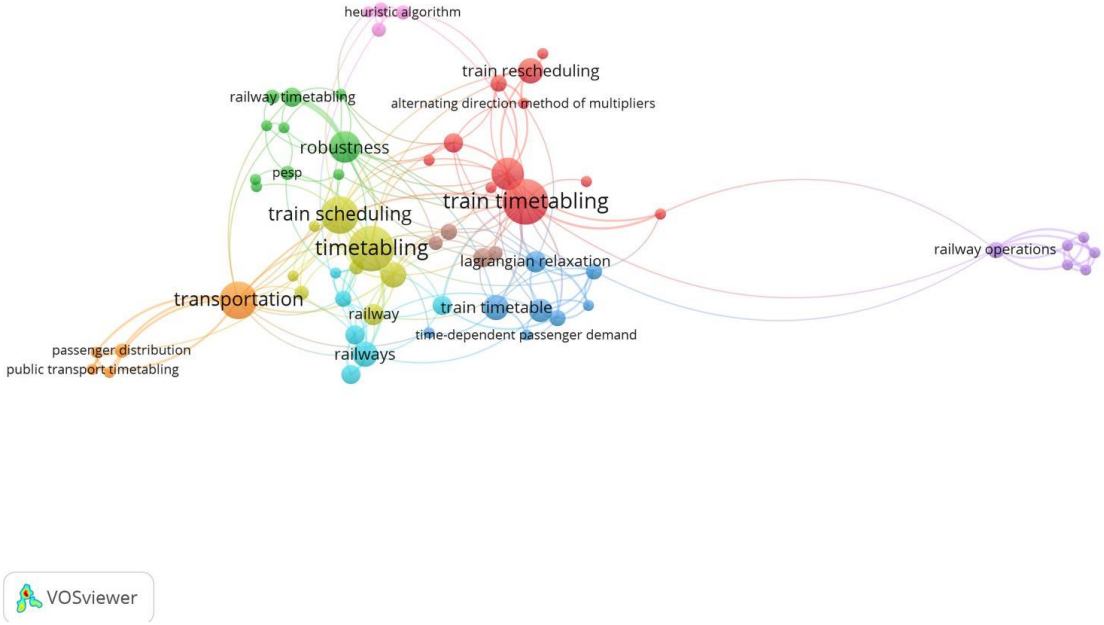

Figure 4 (Source: VOSviewer)

Figure 4 represents the network of title and abstract words used in different articles. It is clearly evident that train timetabling, train scheduling, timetabling consisted most of the title heads.

Analysis of Co-Occurrence of Citation Network:

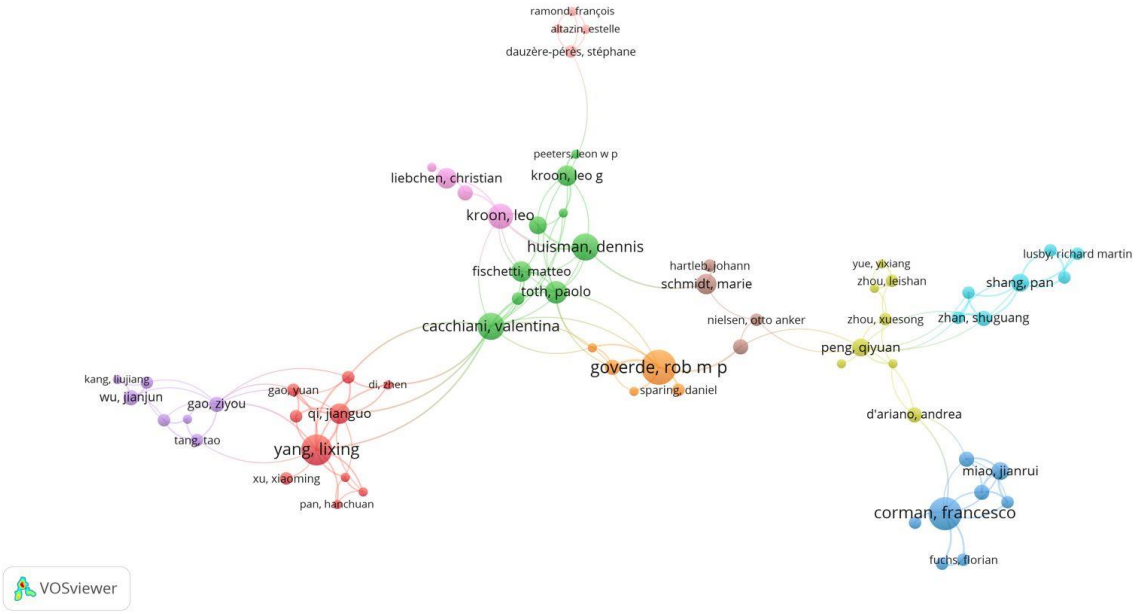

Figure 5 (Source: VOSviewer)

Figure 5 represents the citation networks of selected research papers based on their authors. It can be observed that Rob M P Goverde, Lixing Yang and Francesco Corman were the leading authors in the analysis.

Future Work:

The presented paper involves various methods and techniques which have been used to identify, determine, predict, analyze various possibilities and availabilities in the train scheduling network. Various outcomes which have arrived using permutations and combinations of methods provided sustainable results which could be useful in various areas. The "Alternating Direction Method of Multipliers (ADMM)" Method helped to solve optimization problems by converting them into small elements which in turn helped in generating better options.(Dong, 2020; Sameni, n.d.) The MILP model enabled the generation of structures which in turn led to the better line planning.(Harrod, 2012b) This is just a glimpse of the most popular ones which have been found in the research. There are several other models and methods which have been used to help identify the best solution or the approach which should be used. (Siebert & Goerigk, 2013)

Some research papers used the "PESP(Periodic Event-Scheduling Problem) model or the MILP (Mixed Integer Linear Programming) model" (Cao et al., 2019; Kroon et al., 2014; Van Aken et al., 2017; Zhang & Nie, 2016) (Canca & Zarzo, 2017; Van Aken et al., 2017; Yan et al., 2019). Since some of the models implemented in the previous research papers do not consider the accurate, practical, dynamic implications that are applicable in the concrete world, the development of such models is necessary to precisely interpret case scenarios, plan timetable schedules and routing decisions accordingly. (Caprara et al., 1999; Masoud et al., n.d.)

Models such as "Fuzzy Optimization Model" as implemented in the works of (He et al., 2000b; Murugappan, n.d.; L. Wang et al., 2012; Zhuang et al., 2016a) can be refined upon. Further, the initiation of models and simulations that measure the effectiveness of drawn timetables and route combinations is required to quantify its impact.

IV. CONCLUSION:

This paper is a literature review on the various models that can be used to solve the problems of robust train timetabling(Cacchiani & Toth, 2012b),(Salido et al., 2012)train scheduling and rescheduling, etc.(Yalçinkaya & Mirac Bayhan, 2012) keeping in mind the commercial needs as well as security and capacity constraints.(ARENAS et al., 2015) It has been observed that there have been many publications in this area, however, there are very few review papers.

At the designing level, rail timetabling comprises of "optimizing the routing and scheduling" for a intricate rail network. However, the planned schedule needs to be verified and updated constantly due to disruptions or delays(Altazin et al., 2017; Goverde, 1999) that may require train rerouting or cancellations. In practice, an immediate reaction is required when unexpected events like these occur, implying that trains must be rescheduled in seconds. (Fischetti & Monaci, 2017)

The departure frequency is another aspect that should be kept in mind when it comes to optimal timetabling, which depends on maximum section passenger flow. This flow varies greatly within different sections, and often leads to waste of capacity. (Xue et al., 2019). Reduction in passenger waiting time, costs and efficient utilization of energy and other resources are some other objectives of efficient timetabling(Semet & Schoenauer, 2005). Some complicated concepts of network planning, line planning, railway track allocations, crew schedules, real time management, train order entropy, (Huo et al., 2016)etc. can be solved by using methods of operation research.

However, to solve these problems, traditional time-consuming optimization tools used in the planning phase are proven to be inadequate(Liebchen, 2008), as real world timetabling problems (Cavone et al., 2019; Meng et al., 2020; Sparing & Goverde, 2013; Yamada et al., 2017; J. Zhao et al., 2022)can lead to very large instances that are not solvable by commercial state-of-the-art software. (L. G. Kroon & Peeters, 2003; Liebchen & Möhring, 2008) Traditional methods such as PESP and MILP have proven to be ineffective when used exclusively. However, these models show great extendibility. During the previous year, a

trend towards the integration of various conventional design models have been developed. Study shows timetabling problems in the real world can be successfully attacked by integration of traditional models like PESP and MILP (Pellegrini et al., 2019) with other models, and using new approaches such as the Lagrangian relaxation methods (Fischer et al., 2008). Other methods such as branch and bound algorithmic approach (X. Zhou & Zhong, 2007), stochastic stimulation models, fuzzy linear programming models, macroscopic models, DDS, genetic algorithm(Alwadood et al., 2012; Bahramian & Bagheri, 2015; Li et al., 2019; Liebchen et al., 2005), collaborative optimization method (L. Yang et al., 2016), meta heuristic approaches(Barber et al., 2009)(Rossi-doria & Paechter, 2003), ADMM, etc. are also used. The advantages and disadvantages of all these models have been discussed in this research paper.

This paper also shows A computational analysis on real cases across the world across various timelines and proves that these approaches can be successfully used for practical real-time train rescheduling.

(Cacchiani et al., 2016)tests linear programming formulations to a portion of railway in Liguria. (X. Yang et al., 2014)tests the genetic model with binary encoding on the Beijing Yizhuang subway line of China, as well as the Beijing-Tianjin intercity railway(Kang et al., 2022). (Sparing & Goverde, 2017b) tries implementing the genetic algorithm-based model to the German railways(X. Yang et al., 2013) and on the Dutch railway system. The models have been applied to the Genoa railway network as well(Donzella & Sacile, 2018).

Thus, we can conclude that more work needs to be invested into developing better rounding heuristics. We hope that these models, through their integrative approach to vehicle scheduling, timetabling, line planning, and infrastructure planning, will eventually lead to better decision making in practice.(Bansal Vaishnavi Kumar Vedansh Chopra Vedant Jain Richa Saxena, 2017)

References:

Ahuja, R. K., Liu, J., Orlin, J. B., Sharma, D., & Shughart, L. A. (2005). Solving real-life locomotive-scheduling problems. *Transportation Science*, *39*(4), 503–517. https://doi.org/10.1287/trsc.1050.0115

Alaghband, M., & Moghaddam, B. F. (2022). An optimization model for scheduling freight trains on a single-rail track. *Scientia Iranica*, *29*(2), 853–863. https://doi.org/10.24200/SCI.2020.53538.3304

Albrecht, A. R., Panton, D. M., & Lee, D. H. (2013). Rescheduling rail networks with maintenance disruptions using Problem Space Search. *Computers and Operations Research*, *40*(3), 703–712. https://doi.org/10.1016/j.cor.2010.09.001

Almodóvar, M. G.-R. R. (2013). On-line reschedule optimization for passenger railways in case of emergencies. *Computers and Operations Research*, *40*(3), 725–736. https://doi.org/10.1016/j.cor.2011.01.013

Altazin, E., Dauzère-Pérès, S., Ramond, F., & Tréfond, S. (2017). Rescheduling through stop-skipping in dense railway systems. *Transportation Research Part C: Emerging Technologies*, *79*(2017), 73–84. https://doi.org/10.1016/j.trc.2017.03.012

Alwadood, Z., Shuib, A., & Hamid, N. A. (2012). A Review on Quantitative Models in Railway Rescheduling. *International Journal Of Scientific & Engineering Research*, *3*(6), 1–7. http://www.ijser.org/researchpaper%5CA-Review-on-Quantitative-Models-in-Railway-Rescheduling.pdf

ARENAS, D., CHEVRIER, R., HANAFI, S., & RODRIGUEZ, J. (2015). Solving the train timetabling problem, a mathematical model and a genetic algorithm solution approach. *6Th International Conference on Railway Operations Modelling and Analysis*, 1–13. https://hal.xn--archivesouvertes-jg6i.fr/hal–01338609%0Aand%0Ahttps://hal.archives–ouvertes.fr/hal–01338609/file/Paper_1144939.pdf

Bach, L., Gendreau, M., & Wøhlk, S. (2015). Freight railway operator timetabling and engine scheduling. *European Journal of Operational Research*, *241*(2), 309–319. https://doi.org/10.1016/j.ejor.2014.08.036

Bahramian, Z., & Bagheri, M. (2015). A simulation-based optimization approach for passenger train timetabling with periodic track maintenance and stops for praying. *Journal of Modern Transportation*, *23*(2), 148–157. https://doi.org/10.1007/s40534-015-0077-z

Bansal Vaishnavi Kumar Vedansh Chopra Vedant Jain Richa Saxena, V. (2017). Effective Railway Planning Through Operations Research. *International Journal of Innovative Science and Research Technology*, *2*(11), 66–89. www.ijisrt.com67

Barber, F., Ingolotti, L., Lova, A., Tormos, P., & Salido, M. A. (2009). Meta-heuristic and constraint-based approaches for single-line railway timetabling. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *5868 LNCS*, 145–181. https://doi.org/10.1007/978-3-642-05465-5_6

Barrena, E., Canca, D., Coelho, L. C., & Laporte, G. (2014). Exact formulations and algorithm for the train timetabling problem with dynamic demand. *Computers and Operations Research*, *44*, 66–74. https://doi.org/10.1016/j.cor.2013.11.003

Bešinović, N. E. R. M. P. (2019). Resolving instability in railway timetabling problems. *EURO Journal on Transportation and Logistics*, *8*(5), 833–861. https://doi.org/10.1007/s13676-019-00148-3

Binder, S. ,Maknoon, M. Y. ,Sharif A. S. M. (2021). Passenger-centric timetable rescheduling: A user equilibrium approach. *Transportation Research Part C: Emerging Technologies*, *132*. https://doi.org/10.1016/j.trc.2021.103368

Binder, S., Maknoon, Y., & Bierlaire, M. (2017). The multi-objective railway timetable rescheduling problem. *Transportation Research Part C: Emerging Technologies*, *78*, 78–94. https://doi.org/10.1016/j.trc.2017.02.001

Budai, G., Huisman, D., & Dekker, R. (2006). Scheduling preventive railway maintenance activities - IEEE Xplore Document. *The Journal of the Operational Research Society*, *57*(9), pp.1035-1044.

Burdett, R., & Kozan, E. (2004). *ABSOLUTE CAPACITY DETERMINATION AND TIMETABLING IN RAILWAYS*.

Burdett, R. L., & Kozan, E. (2009). Scheduling trains on parallel lines with crossover points. *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, *13*(4), 171–187. https://doi.org/10.1080/15472450903297608

Burdett, R. L., & Kozan, E. (2010). A sequencing approach for creating new train timetables. *OR Spectrum*, *32*(1), 163–193. https://doi.org/10.1007/s00291-008-0143-6

Bussieck, M. R., Lindner, T., & Lübbecke, M. E. (2004). A fast algorithm for near cost optimal line plans. *Mathematical Methods of Operations Research*, *59*(2), 205–220. https://doi.org/10.1007/s001860300332

Cacchiani, V., Caprara, A., & Fischetti, M. (2012). A lagrangian heuristic for robustness, with an application to train timetabling. *Transportation Science*, *46*(1), 124–133. https://doi.org/10.1287/trsc.1110.0378

Cacchiani, V., Furini, F., & Kidd, M. P. (2016). Approaches to a real-world Train Timetabling Problem in a railway node. *Omega (United Kingdom)*, *58*, 97–110. https://doi.org/10.1016/j.omega.2015.04.006

Cacchiani, V., Huisman, D., Kidd, M., Kroon, L., Toth, P., Veelenturf, L., & Wagenaar, J. (2014). An overview of recovery models and algorithms for real-time railway rescheduling. *Transportation Research Part B: Methodological*, *63*, 15–37. https://doi.org/10.1016/j.trb.2014.01.009

Cacchiani, V., & Toth, P. (2012a). Nominal and robust train timetabling problems. *European Journal of Operational Research*, *219*(3), 727–737. https://doi.org/10.1016/j.ejor.2011.11.003

Cacchiani, V., & Toth, P. (2012b). Nominal and robust train timetabling problems. *European Journal of Operational Research*, *219*(3), 727–737. https://doi.org/10.1016/j.ejor.2011.11.003

Caimi, G., Burkolter, D., & Herrmann, T. (n.d.). *Finding Delay-Tolerant Train Routings through Stations*.

Caimi, G., Kroon, L., & Liebchen, C. (2017a). Models for railway timetable optimization: Applicability and applications in practice. *Journal of Rail Transport Planning and Management*, *6*(4), 285–312. https://doi.org/10.1016/j.jrtpm.2016.11.002

Caimi, G., Kroon, L., & Liebchen, C. (2017b). Models for railway timetable optimization: Applicability and applications in practice. *Journal of Rail Transport Planning and Management*, *6*(4), 285–312. https://doi.org/10.1016/j.jrtpm.2016.11.002

Cao, Z., Ceder, A. (Avi), Li, D., & Zhang, S. (2019). Optimal synchronization and coordination of actual passenger-rail timetables. *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, *23*(3), 231–249. https://doi.org/10.1080/15472450.2018.1488132

Caprara, A., Fischetti, M., & Toth, P. (n.d.). Modeling and Solving the Train Timetabling Problem. In *Operations Research* (Vol. 50, Issue 5).

Caprara, A., Fischetti, M., & Toth, P. (1999). Heuristic method for the set covering problem. *Operations Research*, *47*(5), 730–743. https://doi.org/10.1287/opre.47.5.730

Caset, F., Derudder, B., Witlox, F., Teixeira, F. M., & Boussauw, K. (2019). Planning for nodes, places, and people in Flanders and Brussels. *Journal of Transport and Land Use*, *12*(1), 811–837. https://doi.org/10.2307/26911290

Cavone, G., Blenkers, L., van den Boom, T., Dotoli, M., Seatzu, C., & de Schutter, B. (2019). Railway disruption: A bi-level rescheduling algorithm. *2019 6th International Conference on Control, Decision and Information Technologies, CoDIT 2019*, 54–59. https://doi.org/10.1109/CoDIT.2019.8820380

Chen, D. S. C. X. (2019). Optimizing the draft passenger train timetable based on node importance in a railway network. *Transportation Letters*, *11*(1), 20–32. https://doi.org/10.1080/19427867.2016.1271523

Chen, S., Ho, T., & Mao, B. (2013). Maintenance schedule optimisation for a railway power supply system. *International Journal of Production Research*, *51*(16), 4896–4910. https://doi.org/10.1080/00207543.2013.774501

Chierici, A., Cordone, R., & Maja, R. (2004). The demand-dependent optimization of regular train timetables. *Electronic Notes in Discrete Mathematics*, *17*, 99–104. https://doi.org/10.1016/j.endm.2004.03.017

Cohen, J. M., Barron, A. S., Anderson, R. J., & Graham, D. J. (2015). Impacts of unattended train operations on productivity and efficiency in metropolitan railways. *Transportation Research Record*, *2534*, 75–83. https://doi.org/10.3141/2534-10

Copyright © 1997. All rights reserved. (1997).

Cordeau, J. F., Soumis, F., & Desrosiers, J. (2001). Simultaneous assignment of locomotives and cars to passenger trains. *Operations Research*, *49*(4), 531–548. https://doi.org/10.1287/opre.49.4.531.11226

Cordone, R., & Redaelli, F. (2011). Optimizing the demand captured by a railway system with a regular timetable. *Transportation Research Part B: Methodological*, *45*(2), 430–446. https://doi.org/10.1016/J.TRB.2010.09.001

Corman, F., D'Ariano, A., & Hansen, I. A. (2014). Evaluating disturbance robustness of railway schedules. *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, *18*(1), 106–120. https://doi.org/10.1080/15472450.2013.801714

Corman, F., & Henken, J. (2022a). Estimating aggregate railway performance from realized empirical data: Literature review, a test case and a research roadmap. *Journal of Rail Transport Planning and Management*, *22*. https://doi.org/10.1016/j.jrtpm.2022.100316

Corman, F., & Henken, J. (2022b). Estimating aggregate railway performance from realized empirical data: Literature review, a test case and a research roadmap. *Journal of Rail Transport Planning and Management*, *22*. https://doi.org/10.1016/j.jrtpm.2022.100316

D'Ariano, A., Meng, L., Centulio, G., & Corman, F. (2019). Integrated stochastic optimization approaches for tactical scheduling of trains and railway infrastructure maintenance. *Computers and Industrial Engineering*, *127*, 1315–1335. https://doi.org/10.1016/j.cie.2017.12.010

Dewilde, T., Sels, P., Cattrysse, D., & Vansteenwegen, P. (2014). Improving the robustness in railway station areas. *European Journal of Operational Research*, *235*(1), 276–286. https://doi.org/10.1016/j.ejor.2013.10.062

Dick, C. T. (n.d.-a). *Microsoft Word - Sehitoglu-at-al-TRB-18-3149-Speed-flexibility-and-runtime-FINAL-2017-11-14.*

Dick, C. T. (n.d.-b). *Microsoft Word - Sehitoglu-at-al-TRB-18-3149-Speed-flexibility-and-runtime-FINAL-2017-11-14.*

Ding, S., Zhang, T., Liu, Z., Wang, R., Lu, S., Xin, B., & Yuan, Z. (2022). A Memetic Algorithm for High-Speed Railway Train Timetable Rescheduling. *Journal of Advanced Computational Intelligence and Intelligent Informatics*, *26*(3), 407–417. https://doi.org/10.20965/jaciii.2022.p0407

Dong, X. D. Y. S. Z. (2020). Integrated optimization of train stop planning and timetabling for commuter railways with an extended adaptive large neighborhood search metaheuristic approach. *Transportation Research Part C: Emerging Technologies*, *117*. https://doi.org/10.1016/j.trc.2020.102681

Donzella, F., & Sacile, R. (2018). *Application to Genoa railway network*. 593–600.

Dunkin, Ann., ACM Digital Library., & ACM Special Interest Group on Simulation and Modeling. (2009a). *Winter Simulation Conference*. Winter Simulation Conference.

Dunkin, Ann., ACM Digital Library., & ACM Special Interest Group on Simulation and Modeling. (2009b). *Winter Simulation Conference*. Winter Simulation Conference.

Engelhardt-Funke, O., & Kolonko, M. (2004). Analysing stability and investments in railway networks using advanced evolutionary algorithms. *International Transactions in Operational Research*, *11*(4), 381–394. https://doi.org/10.1111/j.1475-3995.2004.00465.x

Fischer, F., Helmberg, C., Janßen, J., & Krostitz, B. (2008). Towards solving very large scale train timetabling problems by lagrangian relaxation. *OpenAccess Series in Informatics*, *9*, 1–12.

Fischetti, M., & Monaci, M. (2017). Using a general-purpose Mixed-Integer Linear Programming solver for the practical solution of real-time train rescheduling. *European Journal of Operational Research*, *263*(1), 258–264. https://doi.org/10.1016/j.ejor.2017.04.057

Florian, M., Bushell, G., Ferland, J., Guerin, G., & Nastansky, L. (1976). ENGINE SCHEDULING PROBLEM IN A RAILWAY NETWORK. *INFOR Journal*, *14*(2), 121–138. https://doi.org/10.1080/03155986.1976.11731632

Fuchs, F. T. A. C. F. (2022). Enhancing the interaction of railway timetabling and line planning with infrastructure awareness. *Transportation Research Part C: Emerging Technologies*, *142*, 103805. https://doi.org/10.1016/j.trc.2022.103805

Fuchs, F., Trivella, A., & Corman, F. (2021). Enhancing the interaction of railway timetabling and line planning with infrastructure awareness. *SSRN Electronic Journal*, *142*(July), 103805. https://doi.org/10.2139/ssrn.3938934

Gao, R., & Niu, H. (2021). A priority-based ADMM approach for flexible train scheduling problems. *Transportation Research Part C: Emerging Technologies*, *123*. https://doi.org/10.1016/j.trc.2020.102960

Ghoseiri, K., Szidarovszky, F., & Asgharpour, M. J. (2004). A multi-objective train scheduling model and solution. *Transportation Research Part B: Methodological*, *38*(10), 927–952. https://doi.org/10.1016/j.trb.2004.02.004

Gong, C., Shi, J., Wang, Y., Zhou, H., Yang, L., Chen, D., & Pan, H. (2021). Train timetabling with dynamic and random passenger demand: A stochastic optimization method. *Transportation Research Part C: Emerging Technologies*, *123*. https://doi.org/10.1016/j.trc.2021.102963

Goverde, R. M. P. (1999). Improving Punctuality and Transfer Reliability by Railway Timetable Optimization. *Proceedings of the 5th TRAIL Annual Congress*, *December*.

Goverde, R. M. P., Bešinović, N., Binder, A., Cacchiani, V., Quaglietta, E., Roberti, R., & Toth, P. (2016). A three-level framework for performance-based railway timetabling. *Transportation Research Part C: Emerging Technologies*, *67*, 62–83. https://doi.org/10.1016/j.trc.2016.02.004

Goverde, R. M. P., & Hansen, I. A. (2013). Performance indicators for railway timetables. *IEEE ICIRT 2013 - Proceedings: IEEE International Conference on Intelligent Rail Transportation*, 301–306. https://doi.org/10.1109/ICIRT.2013.6696312

Hansen, I. A. (2006). State-of-the-art of railway operations research. *WIT Transactions on the Built Environment*, *88*, 565–577. https://doi.org/10.2495/CR060561

Harrod, S. S. (2012a). A tutorial on fundamental model structures for railway timetable optimization. *Surveys in Operations Research and Management Science*, *17*(2), 85–96. https://doi.org/10.1016/j.sorms.2012.08.002

Harrod, S. S. (2012b). A tutorial on fundamental model structures for railway timetable optimization. In *Surveys in Operations Research and Management Science* (Vol. 17, Issue 2, pp. 85–96). https://doi.org/10.1016/j.sorms.2012.08.002

Hartleb, J. S. M. (2022). Railway timetabling with integrated passenger distribution. *European Journal of Operational Research*, *298*(3), 953–966. https://doi.org/10.1016/j.ejor.2021.06.025

Hartleb, J., & Schmidt, M. (2022). Railway timetabling with integrated passenger distribution. *European Journal of Operational Research*, *298*(3), 953–966. https://doi.org/10.1016/j.ejor.2021.06.025

Hassannayebi, E., Zegordi, S. H., Yaghini, M., & Amin-Naseri, M. R. (2017). Timetable optimization models and methods for minimizing passenger waiting time at public transit terminals. *Transportation Planning and Technology*, *40*(3), 278–304. https://doi.org/10.1080/03081060.2017.1283156

He, S., Song, R., & Chaudhry, S. S. (2000a). Fuzzy dispatching model and genetic algorithms for railyards operations. *European Journal of Operational Research*, *124*(2), 307–331. https://doi.org/10.1016/S0377-2217(99)00383-5

He, S., Song, R., & Chaudhry, S. S. (2000b). Fuzzy dispatching model and genetic algorithms for railyards operations. *European Journal of Operational Research*, *124*(2), 307–331. https://doi.org/10.1016/S0377-2217(99)00383-5

Herrigel, S. M. J. U. (2018). Periodic railway timetabling with sequential decomposition in the PESP model. *Journal of Rail Transport Planning and Management*, *8*(3–4), 167–183. https://doi.org/10.1016/j.jrtpm.2018.09.003

Högdahl, J., Bohlin, M., & Fröidh, O. (2019). A combined simulation-optimization approach for minimizing travel time and delays in railway timetables. *Transportation Research Part B: Methodological*, *126*, 192–212. https://doi.org/10.1016/j.trb.2019.04.003

Huang, K., Wu, J., Liao, F., Sun, H., He, F., & Gao, Z. (2021). Incorporating multimodal coordination into timetabling optimization of the last trains in an urban railway network. *Transportation Research Part C: Emerging Technologies*, *124*. https://doi.org/10.1016/j.trc.2020.102889

Huang, Z., Zhang, Y., Zhang, Z., & Yang, L. (2022). Optimization of train timetables in high-speed railway corridors considering passenger departure time and seat-class preferences. *Transportation Letters*. https://doi.org/10.1080/19427867.2022.2037332

Huisman, D., Kroon, L. G., Lentink, R. M., Vromans, M. J. C. M., Huisman, D., Kroon, L. G., Lentink, R. M., & Vromans, M. J. C. M. (2005). Operations research in passenger railway transportation. *Statistica Neerlandica*, *59*(4), 467–497. https://doi.org/10.1111/j.1467-9574.2005.00303.x

Huo, J., Wu, J., Kang, L., & Wang, B. (2016). Railway Timetable Rescheduling Based on Priority and Train Order Entropy. *Journal of Computing in Civil Engineering*, *30*(5). https://doi.org/10.1061/(asce)cp.1943-5487.0000559

Içyüz-Ay, I. E., Richard, J. P. P., Eskigun, E., & Acharya, D. (2016). A two-model solution approach for the monthly coal train reservations planning problem. *Transportation Science*, *50*(3), 926–946. https://doi.org/10.1287/trsc.2015.0654

Jafarian-Moghaddam, A. R. (2021). Elastic train scheduling model. *Applied Soft Computing*, *110*. https://doi.org/10.1016/j.asoc.2021.107627

Jensen, L. W., Schmidt, M., & Nielsen, O. A. (2020). *Determination of infrastructure capacity in railway networks without the need for a fixed timetable*. https://doi.org/10.1016/j.trc.2020.102751

Kang, L., Xiao, Y., Sun, H., Wu, J., Luo, S., & Buhigiro, N. (2022). Decisions on train rescheduling and locomotive assignment during the COVID-19 outbreak: A case of the Beijing-Tianjin intercity railway. *Decision Support Systems*, *161*(May), 113600. https://doi.org/10.1016/j.dss.2021.113600

Ke, B. R., Lin, C. L., Chien, H. H., Chiu, H. W., & Chen, N. (2015). A new approach for improving the performance of freight train timetabling of a single-track railway system. *Transportation Planning and Technology*, *38*(2), 238–264. https://doi.org/10.1080/03081060.2014.959357

Kotsiopoulos, I. L. (1999). Railway operating procedures: Regulating a safety-critical enterprise. *Computers in Industry*, *40*(2), 221–230. https://doi.org/10.1016/S0166-3615(99)00026-3

Kroon, L. G., & Peeters, L. W. P. (2003). A variable trip time model for cyclic railway timetabling. *Transportation Science*, *37*(2), 198–212. https://doi.org/10.1287/trsc.37.2.198.15247

Kroon, L. G., Peeters, L. W. P., Wagenaar, J. C., & Zuidwijk, R. A. (2014). Flexible connections in PESP models for cyclic passenger railway timetabling. *Transportation Science*, *48*(1), 136–154. https://doi.org/10.1287/trsc.1120.0453

Kroon, L., & Huisman, D. (n.d.). *Algorithmic Support for Disruption Management at Netherlands Railways*.

Kroon, L., Huisman, D., Abbink, E., Fioole, P. J., Fischetti, M., Maróti, G., Schrijver, A., Steenbeek, A., & Ybema, R. (2009). The new Dutch timetable: The OR revolution. *Interfaces*, *39*(1), 6–17. https://doi.org/10.1287/inte.1080.0409

Kroon, L., Huisman, D., & Maróti, G. (n.d.-a). *Railway Timetabling from an Operations Research Perspective Econometric Institute Report EI2007-22*.

Kroon, L., Huisman, D., & Maróti, G. (n.d.-b). *Railway Timetabling from an Operations Research Perspective Econometric Institute Report EI2007-22*.

Kroon, L., Maróti, G., Helmrich, M. R., Vromans, M., & Dekker, R. (2008). Stochastic improvement of cyclic railway timetables. *Transportation Research Part B: Methodological*, *42*(6), 553–570. https://doi.org/10.1016/j.trb.2007.11.002

Kumar, R. (2001). *Applying Operations Research to Railway Operations*. 1–13.

Kümmling, M., Großmann, P., Nachtigall, K., Opitz, J., & Weiß, R. (2015). A state-of-the-art realization of cyclic railway timetable computation. *Public Transport*, *7*(3), 281–293. https://doi.org/10.1007/s12469-015-0108-5

Lamorgese, L., & Mannino, C. (2015). An exact decomposition approach for the real-time train dispatching problem. *Operations Research*, *63*(1), 48–64. https://doi.org/10.1287/opre.2014.1327

Lamorgese, L., Mannino, C., & Natvig, E. (2017). An exact micro–macro approach to cyclic and non-cyclic train timetabling. *Omega (United Kingdom)*, *72*, 59–70. https://doi.org/10.1016/j.omega.2016.11.004

Larsen, R., Pranzo, M., D'Ariano, A., Corman, F., & Pacciarelli, D. (2014). Susceptibility of optimal train schedules to stochastic disturbances of process times. *Flexible Services and Manufacturing Journal*, *26*(4), 466–489. https://doi.org/10.1007/s10696-013-9172-9

Li, X., Meng, L., Wang, Y., Long, S., & Miao, J. (2019). A rescheduling optimization model under temporary speed restriction. *2019 IEEE Intelligent Transportation Systems Conference, ITSC 2019*, *86*, 3726–3731. https://doi.org/10.1109/ITSC.2019.8916846

Liao, Z. J. L. H. (2022). A resource-oriented decomposition approach for train timetabling problem with variant running time and minimum headway. *Transportation Letters*, *14*(2), 129–142. https://doi.org/10.1080/19427867.2020.1824310

Liao, Z., Li, H., Miao, J., & Corman, F. (2021). Railway capacity estimation considering vehicle circulation: Integrated timetable and vehicles scheduling on hybrid time-space networks. *Transportation Research Part C: Emerging Technologies*, *124*(November 2020), 102961. https://doi.org/10.1016/j.trc.2020.102961

Liebchen, C. (2008). The first optimized railway timetable in practice. *Transportation Science*, *42*(4), 420–435. https://doi.org/10.1287/trsc.1080.0240

Liebchen, C., & Möhring, R. H. (2008). The modeling power of the periodic event scheduling problem: Railway timetables - and beyond. *Lecture Notes in Economics and Mathematical Systems*, *600*, 117–150. https://doi.org/10.1007/978-3-540-73312-6_7

Liebchen, C., Proksch, M., & Wagner, F. H. (2005). *Optimization. 1997*.

Liebchen, C., Schachtebeck, M., Schöbel, A., Stiller, S., & Prigge, A. (2010). Computing delay resistant railway timetables. *Computers & Operations Research*, *37*(5), 857–868. https://doi.org/10.1016/J.COR.2009.03.022

Liu, S. Q., & Kozan, E. (2009). Scheduling trains as a blocking parallel-machine job shop scheduling problem. *Computers and Operations Research*, *36*(10), 2840–2852. https://doi.org/10.1016/j.cor.2008.12.012

Lu, C., Tang, J., Zhou, L., Yue, Y., & Huang, Z. (2017). Improving recovery-to-optimality robustness through efficiency-balanced design of timetable structure. *Transportation Research Part C: Emerging Technologies*, *85*(September), 184–210. https://doi.org/10.1016/j.trc.2017.09.015

Lusby, R. M., Larsen, J., Ehrgott, M., & Ryan, D. (2011). Railway track allocation: Models and methods. In *OR Spectrum* (Vol. 33, Issue 4, pp. 843–883). https://doi.org/10.1007/s00291-009-0189-0

Martin-Iradi, B., & Ropke, S. (2022). A column-generation-based matheuristic for periodic and symmetric train timetabling with integrated passenger routing. *European Journal of Operational Research*, *297*(2), 511–531. https://doi.org/10.1016/j.ejor.2021.04.041

Masoud, M., Kozan, E., & Kent, G. A. (n.d.). *M 24. A NEW APPROACH TO AUTOMATICALLY PRODUCING SCHEDULES FOR CANE RAILWAYS*.

Matière, en, & Juin, B. (1973). *Compte Rendu Proceedings de la Conference Internationale sur la Recherche of the International Conference on Transportation Research de Transport PREMIERE CONFERENCE FIRST CONFERENCE*.

Meng, X., Wang, Y., Xiang, W., & Jia, L. (2020). An integrated model for train rescheduling and station track assignment. *IET Intelligent Transport Systems*, *October 2020*, 17–30. https://doi.org/10.1049/itr2.12001

Murugappan, M. (n.d.). *Railway Route Optimization System Using Fuzzy Dijkstra's Algorithm Neutrosophic Optimization View project A study on Fuzzy L-ideals and Fuzzy L-Filters View project*. https://www.researchgate.net/publication/315527020

Nemani, A. K., Bog, S., & Ahuja, R. K. (2010). Solving the curfew planning problem. *Transportation Science*, *44*(4), 506–523. https://doi.org/10.1287/trsc.1100.0323

Ning, J., Peng, Q., Zhu, Y., Jiang, Y., & Nielsen, O. A. (2022). A Bi-objective optimization model for the last train timetabling problem. *Journal of Rail Transport Planning & Management*, *23*, 100333. https://doi.org/10.1016/j.jrtpm.2022.100333

Odijk, M. A. (1996). A constraint generation algorithm for the construction of periodic railway timetables. *Transportation Research Part B: Methodological*, *30*(6), 455–464. https://doi.org/10.1016/0191-2615(96)00005-7

Oh, S. J. (2021). An optimization method to design a skip–stop pattern for renovating operation schemes in urban railways. *Transportation Letters*. https://doi.org/10.1080/19427867.2021.1955566

Oh, Y., Byon, Y. J., Song, J. Y., Kwak, H. C., & Kang, S. (2020). Dwell time estimation using real-time train operation and smart card-based passenger data: A case study in seoul, south korea. *Applied Sciences (Switzerland)*, *10*(2). https://doi.org/10.3390/app10020476

Pan, H., Yang, L., & Liang, Z. (2022). Demand-oriented integration optimization of train timetabling and rolling stock circulation planning with flexible train compositions: A column-generation-based approach. *European Journal of Operational Research*. https://doi.org/10.1016/j.ejor.2022.05.039

Pan, Z., Chen, M., Lu, S., Tian, Z., & Liu, Y. (2020). Integrated Timetable Optimization for Minimum Total Energy Consumption of an AC Railway System. *IEEE Transactions on Vehicular Technology*, *69*(4), 3641–3653. https://doi.org/10.1109/TVT.2020.2975603

Parbo, J., Nielsen, O. A., & Prato, C. G. (2016). Passenger Perspectives in Railway Timetabling: A Literature Review. *Transport Reviews*, *36*(4), 500–526. https://doi.org/10.1080/01441647.2015.1113574

Pascariu, B. N. A. (2021). Railway freight node capacity evaluation: A timetable-saturation approach and its application to the Novara freight terminal. *Transportation Research Procedia*, *52*, 155–162. https://doi.org/10.1016/j.trpro.2021.01.017

Pätzold, J., & Schöbel, A. (2016). A matching approach for periodic timetabling. *OpenAccess Series in Informatics*, *54*, 1.1-1.15. https://doi.org/10.4230/OASIcs.ATMOS.2016.1

Pellegrini, P., Pesenti, R., & Rodriguez, J. (2019). Efficient train re-routing and rescheduling: Valid inequalities and reformulation of RECIFE-MILP. *Transportation Research Part B: Methodological*, *120*, 33–48. https://doi.org/10.1016/j.trb.2018.12.008

Pender, B., Currie, G., Delbosc, A., & Shiwakoti, N. (2013). Disruption recovery in passenger railways. *Transportation Research Record*, *2353*, 22–32. https://doi.org/10.3141/2353-03

Petering, M. E. H., Heydar, M., & Bergmann, D. R. (2016). Mixed-integer programming for railway capacity analysis and cyclic, combined train timetabling and platforming. *Transportation Science*, *50*(3), 892–909. https://doi.org/10.1287/trsc.2015.0652

Polinder, G. J., Schmidt, M., & Huisman, D. (2021). Timetabling for strategic passenger railway planning. *Transportation Research Part B: Methodological*, *146*, 111–135. https://doi.org/10.1016/j.trb.2021.02.006

Qi, J., Cacchiani, V., Yang, L., Zhang, C., & Di, Z. (2021). An Integer Linear Programming model for integrated train stop planning and timetabling with time-dependent passenger demand. *Computers and Operations Research*, *136*(December 2020), 105484. https://doi.org/10.1016/j.cor.2021.105484

Qi, J., Li, S., Gao, Y., Yang, K., & Liu, P. (2018a). Joint optimization model for train scheduling and train stop planning with passengers distribution on railway corridors. *Journal of the Operational Research Society*, *69*(4), 556–570. https://doi.org/10.1057/s41274-017-0248-x

Qi, J., Li, S., Gao, Y., Yang, K., & Liu, P. (2018b). Joint optimization model for train scheduling and train stop planning with passengers distribution on railway corridors. *Journal of the Operational Research Society*, *69*(4), 556–570. https://doi.org/10.1057/s41274-017-0248-x

RAILWAY ROUTE OPTIMIZATION SYSTEM CASE STUDY: Kasese Railway station. (n.d.). https://doi.org/10.13140/RG.2.2.21530.18880

Rangaraj, N. (2005). An analysis of cyclic timetables for suburban railway services. *Abhivyakti, Journal of the Railway Staff College, Vadodara*. http://www.ieor.iitb.ac.in/files/faculty/narayan/cyclic-timetables.pdf

Reisch, J., Großmann, P., Pöhle, D., & Kliewer, N. (2021). Conflict resolving – A local search algorithm for solving large scale conflict graphs in freight railway timetabling. *European Journal of Operational Research*, *293*(3), 1143–1154. https://doi.org/10.1016/j.ejor.2021.01.006

Reynolds, E., & Maher, S. J. (2022). A data-driven, variable-speed model for the train timetable rescheduling problem. *Computers and Operations Research*, *142*. https://doi.org/10.1016/j.cor.2022.105719

Rossi-doria, O., & Paechter, B. (2003). An hyperheuristic approach to course timetabling problem using an evolutionary algorithm. *Evolutionary Computation, January 2014*. https://www.researchgate.net/publication/228724044

Salido, M. A., Barber, F., & Ingolotti, L. (2012). Robustness for a single railway line: Analytical and simulation methods. *Expert Systems with Applications*, *39*(18), 13305–13327. https://doi.org/10.1016/j.eswa.2012.05.071

Sameni, K. (n.d.). *General rights Capacity Utilization in European Railways Who is the fairest of them all?* http://amonline.trb.org/2velac/2velac/1

Scheidt, M. (n.d.). *Train Slots: A Proposal for Open Access Railways*. https://doi.org/10.24355/dbbs.084-201912091020-0

Schüpbach, K., Caimi, G., Jordi, & Julian. (n.d.). *Towards Automated Capacity Planning in Railways*.

Sels, P., Dewilde, T., Cattrysse, D., & Vansteenwegen, P. (2016). Reducing the passenger travel time in practice by the automated construction of a robust railway timetable. *Transportation Research Part B: Methodological*, *84*, 124–156. https://doi.org/10.1016/j.trb.2015.12.007

Semet, Y., & Schoenauer, M. (2005). An efficient memetic, permutation-based evolutionary algorithm for real-world train timetabling. *2005 IEEE Congress on Evolutionary Computation, IEEE CEC 2005. Proceedings*, *3*, 2752–2759. https://doi.org/10.1109/cec.2005.1555040

Setyawan, E. B., & Diah Damayanti, D. (2018). Integrated railway timetable scheduling optimization model and rescheduling recovery optimization model: A systematic literature review. *2018 5th International Conference on Industrial Engineering and Applications, ICIEA 2018*, 226–230. https://doi.org/10.1109/IEA.2018.8387101

Sevaux, M., & le Quéré, Y. (2003). *Solving a robust maintenance scheduling problem at the french railways company*.

Shu, J., Teo, C. P., & Shen, Z. J. M. (2005). Stochastic transportation-inventory network design problem. *Operations Research*, *53*(1), 48–60. https://doi.org/10.1287/opre.1040.0140

Siebert, M., & Goerigk, M. (2013). An experimental comparison of periodic timetabling models. *Computers and Operations Research*, *40*(10), 2251–2259. https://doi.org/10.1016/j.cor.2013.04.002

Sparing, D., & Goverde, R. M. P. (2013). An optimization model for periodic timetable generation with dynamic frequencies. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, *Itsc*, 785–790. https://doi.org/10.1109/ITSC.2013.6728327

Sparing, D., & Goverde, R. M. P. (2017a). A cycle time optimization model for generating stable periodic railway timetables. *Transportation Research Part B: Methodological*, *98*(434), 198–223. https://doi.org/10.1016/j.trb.2016.12.020

Sparing, D., & Goverde, R. M. P. (2017b). A cycle time optimization model for generating stable periodic railway timetables. *Transportation Research Part B: Methodological*, *98*(434), 198–223. https://doi.org/10.1016/j.trb.2016.12.020

Srivastava, S. C., Mathur, S. S., & Teo, T. S. H. (2009). Competing technology options and stakeholder interests for tracking freight railcars in Indian Railways. *Journal of Information Technology*, *24*(4), 392–400. https://doi.org/10.1057/jit.2009.9

Sun, Y., Cao, C., & Wu, C. (2014). Multi-objective optimization of train routing problem combined with train scheduling on a high-speed railway network. *Transportation Research Part C: Emerging Technologies*, *44*, 1–20. https://doi.org/10.1016/j.trc.2014.02.023

Törnquist, J. (n.d.). *Computer-based decision support for railway traffic scheduling and dispatching: A review of models and algorithms*. http://drops.dagstuhl.de/opus/volltexte/2006/659

Van Aken, S., Bešinović, N., & Goverde, R. M. P. (2017). Designing alternative railway timetables under infrastructure maintenance possessions. *Transportation Research Part B: Methodological*, *98*, 224–238. https://doi.org/10.1016/j.trb.2016.12.019

Veelenturf, L. P., Kidd, M. P., Cacchiani, V., Kroon, L. G., & Toth, P. (2014). *A railway timetable rescheduling approach for handling large scale disruptions*. http://ssrn.com/abstract=2472934

Veelenturf, L. P., Kroon, L. G., & Maróti, G. (2017). Passenger oriented railway disruption management by adapting timetables and rolling stock schedules. *Transportation Research Part C: Emerging Technologies*, *80*, 133–147. https://doi.org/10.1016/j.trc.2017.04.012

Verma, A., & Pattanaik, K. K. (2015). Multi-Agent Communication Based Train Control System for Indian Railways: The Structural Design. *Journal of Software*, *10*(3), 250–259. https://doi.org/10.17706/jsw.10.3.250-259

Vijay, V., & Prasad, D. (n.d.). *Productivity Challenges: A Case of Indian Railways*. https://pramanaresearch.org/

Vorobyov, V., Manakov, A., Reger, A., & Tanaino, I. (2018). Optimization of processes in railways based on the cost management model. *MATEC Web of Conferences*, *216*. https://doi.org/10.1051/matecconf/201821602009

Wang, D., D'Ariano, A., Zhao, J., Zhong, Q., & Peng, Q. (2022). Integrated rolling stock deadhead routing and timetabling in urban rail transit lines. *European Journal of Operational Research*, *298*(2), 526–559. https://doi.org/10.1016/j.ejor.2021.05.053

Wang, L., Qin, Y., Xu, J., & Jia, L. (2012). A fuzzy optimization model for high-speed railway timetable rescheduling. *Discrete Dynamics in Nature and Society*, *2012*. https://doi.org/10.1155/2012/827073

Wang, M., Wang, L., Xu, X., Qin, Y., & Qin, L. (2019). Genetic Algorithm-Based Particle Swarm Optimization Approach to Reschedule High-Speed Railway Timetables: A Case Study in China. *Journal of Advanced Transportation*, *2019*, 13–16. https://doi.org/10.1155/2019/6090742

Wang, R., Zhou, M., Li, Y., Zhang, Q., & Dong, H. (2019). A Timetable Rescheduling Approach for Railway based on Monte Carlo Tree Search; A Timetable Rescheduling Approach for Railway based on Monte Carlo Tree Search. In *2019 IEEE Intelligent Transportation Systems Conference (ITSC)*. https://doi.org/10.0/Linux-x86_64

Wang, Y., & Li, X. (2022). Optimality analysis of train platforming and routing with different interlocking modes. *Communications in Transportation Research*, *2*. https://doi.org/10.1016/j.commtr.2022.100061

Wang, Y., Lv, Y., Zhou, J., Yuan, Z., Zhang, Q., & Zhou, M. (2021). A Policy-Based Reinforcement Learning Approach for High-Speed Railway Timetable Rescheduling. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, *2021-September*, 2362–2367. https://doi.org/10.1109/ITSC48978.2021.9564980

Warg, J. M. (2016). The use of railway simulation as an input to economic assessment of timetables. *Journal of Rail Transport Planning and Management*, *6*(3), 255–270. https://doi.org/10.1016/j.jrtpm.2016.08.001

Xu, X., Li, C. L., & Xu, Z. (2021). Train timetabling with stop-skipping, passenger flow, and platform choice considerations. *Transportation Research Part B: Methodological*, *150*(July 2020), 52–74. https://doi.org/10.1016/j.trb.2021.06.001

Xu, Y., Jia, B., Li, X., Li, M., & Ghiasi, A. (2020). An integrated micro-macro approach for high-speed railway energy-efficient timetabling problem. *Transportation Research Part C: Emerging Technologies*, *112*, 88–115. https://doi.org/10.1016/j.trc.2020.01.008

Xue, Q., Yang, X., Wu, J., Sun, H., Yin, H., & Qu, Y. (2019). Urban rail timetable optimization to improve operational efficiency with flexible routing plans: A nonlinear integer programming model. *Sustainability (Switzerland)*, *11*(13). https://doi.org/10.3390/su11133701

Yalçinkaya, Ö., & Mirac Bayhan, G. (2012). A feasible timetable generator simulation modelling framework for train scheduling problem. *Simulation Modelling Practice and Theory*, *20*(1), 124–141. https://doi.org/10.1016/j.simpat.2011.09.005

Yamada, T., Sato, T., Oguma, K., & Miyauchi, T. (2017). A study on real-time rescheduling with delayed departure control using linear programming. *2017 IEEE 10th International Workshop on Computational Intelligence and Applications, IWCIA 2017 - Proceedings*, *2017-Decem*, 3–4. https://doi.org/10.1109/IWCIA.2017.8203552

Yan, F., Bešinović, N., & Goverde, R. M. P. (2019). Multi-objective periodic railway timetabling on dense heterogeneous railway corridors. *Transportation Research Part B: Methodological*, *125*, 52–75. https://doi.org/10.1016/j.trb.2019.05.002

Yan, F., & Goverde, R. M. P. (2019). Combined line planning and train timetabling for strongly heterogeneous railway lines with direct connections. *Transportation Research Part B: Methodological*, *127*, 20–46. https://doi.org/10.1016/j.trb.2019.06.010

Yang, L., Qi, J., Li, S., & Gao, Y. (2016). Collaborative optimization for train scheduling and train stop planning on high-speed railways. *Omega (United Kingdom)*, *64*, 57–76. https://doi.org/10.1016/j.omega.2015.11.003

Yang, X., Li, X., Gao, Z., Wang, H., & Tang, T. (2013). A cooperative scheduling model for timetable optimization in subway systems. *IEEE Transactions on Intelligent Transportation Systems*, *14*(1), 438–447. https://doi.org/10.1109/TITS.2012.2219620

Yang, X., Ning, B., Li, X., & Tang, T. (2014). A two-objective timetable optimization model in subway systems. *IEEE Transactions on Intelligent Transportation Systems*, *15*(5), 1913–1921. https://doi.org/10.1109/TITS.2014.2303146

Yin, J., Tang, T., Yang, L., Xun, J., Huang, Y., & Gao, Z. (2017). Research and development of automatic train operation for railway transportation systems: A survey. In *Transportation Research Part C: Emerging Technologies* (Vol. 85, pp. 548–572). Elsevier Ltd. https://doi.org/10.1016/j.trc.2017.09.009

Yue, Y., Wang, S., Zhou, L., Tong, L., & Saat, M. R. (2016). Optimizing train stopping patterns and schedules for high-speed passenger rail corridors. *Transportation Research Part C: Emerging Technologies*, *63*, 126–146. https://doi.org/10.1016/j.trc.2015.12.007

Zhan, S., Kroon, L. G., Veelenturf, L. P., & Wagenaar, J. C. (2015). Real-time high-speed train rescheduling in case of a complete blockage. *Transportation Research Part B: Methodological*, *78*, 182–201. https://doi.org/10.1016/j.trb.2015.04.001

Zhan, S. S. C. ,Shang, P. Q. J. S. M. (2021). Integrated railway timetable rescheduling and dynamic passenger routing during a complete blockage. *Transportation Research Part B: Methodological*, *143*, 86–123. https://doi.org/10.1016/j.trb.2020.11.006

Zhan, S. W. S. C. L. S. M. (2020). Social equity-based timetabling and ticket pricing for high-speed railways. *Transportation Research Part A: Policy and Practice*, *137*, 165–186. https://doi.org/10.1016/j.tra.2020.04.018

Zhang, Q. L. R. M. P. X. (2022). A heuristic approach to integrate train timetabling, platforming, and railway network maintenance scheduling decisions. *Transportation Research Part B: Methodological*, *158*, 210–238. https://doi.org/10.1016/j.trb.2022.02.002

Zhang, Q., Lusby, R. M., Shang, P., & Zhu, X. (2020). Simultaneously re-optimizing timetables and platform schedules under planned track maintenance for a high-speed railway network. *Transportation Research Part C: Emerging Technologies*, *121*. https://doi.org/10.1016/j.trc.2020.102823

Zhang, X., & Nie, L. (2016). Integrating capacity analysis with high-speed railway timetabling: A minimum cycle time calculation model with flexible overtaking constraints and intelligent enumeration. *Transportation Research Part C: Emerging Technologies*, *68*, 509–531. https://doi.org/10.1016/j.trc.2016.05.005

Zhang, Y., Guo, J., & An, M. (2022). Development of a railway out-of-gauge freight transport routing optimal method. *Physica A: Statistical Mechanics and Its Applications*, *595*. https://doi.org/10.1016/j.physa.2022.127081

Zhang, Y., Peng, Q., Lu, G., Zhong, Q., Yan, X., & Zhou, X. (2022). Integrated line planning and train timetabling through price-based cross-resolution feedback mechanism. *Transportation Research Part B: Methodological*, *155*(October 2021), 240–277. https://doi.org/10.1016/j.trb.2021.11.009

Zhao, J., Li, H., Meng, L., & Miao, J. (2022). An Optimization Method of High-Speed Railway Rescheduling to Meet Unexpected Large Passenger Flow. *Journal of Advanced Transportation*, *2022*, 1–16. https://doi.org/10.1155/2022/5964010

Zhao, S., Wu, R., & Shi, F. (2021). A line planning approach for high-speed railway network with time-varying demand. *Computers and Industrial Engineering*, *160*(July), 107547. https://doi.org/10.1016/j.cie.2021.107547

Zhi, L. (2019). A common model for railway train timetable optimization. *Proceedings - 2019 11th International Conference on Measuring Technology and Mechatronics Automation, ICMTMA 2019*, 115–119. https://doi.org/10.1109/ICMTMA.2019.00032

Zhong, J. H., Shen, M., Zhang, J., Chung, H. S. H., Shi, Y. H., & Li, Y. (2013). A differential evolution algorithm with dual populations for solving periodic railway timetable scheduling problem. *IEEE Transactions on Evolutionary Computation*, *17*(4), 512–527. https://doi.org/10.1109/TEVC.2012.2206394

Zhou, L., Tong, L. (Carol), Chen, J., Tang, J., & Zhou, X. (2017). Joint optimization of high-speed train timetables and speed profiles: A unified modeling approach using space-time-speed grid networks. *Transportation Research Part B: Methodological*, *97*, 157–181. https://doi.org/10.1016/j.trb.2017.01.002

Zhou, X., & Zhong, M. (2007). Single-track train timetabling with guaranteed optimality: Branch-and-bound algorithms with enhanced lower bounds. *Transportation Research Part B: Methodological*, *41*(3), 320–341. https://doi.org/10.1016/j.trb.2006.05.003

Zhu, Y., & Goverde, R. M. P. (2019). Railway timetable rescheduling with flexible stopping and flexible short-turning during disruptions. *Transportation Research Part B: Methodological*, *123*, 149–181. https://doi.org/10.1016/j.trb.2019.02.015

Zhu, Y., & Goverde, R. M. P. (2020). Integrated timetable rescheduling and passenger reassignment during railway disruptions. *Transportation Research Part B: Methodological*, *140*, 282–314. https://doi.org/10.1016/j.trb.2020.09.001

Zhu, Y., & Goverde, R. M. P. (2021). Dynamic railway timetable rescheduling for multiple connected disruptions. *Transportation Research Part C: Emerging Technologies*, *125*(February), 103080. https://doi.org/10.1016/j.trc.2021.103080

Zhu, Y., Mao, B., Bai, Y., & Chen, S. (2017). A bi-level model for single-line rail timetable design with consideration of demand and capacity. *Transportation Research Part C: Emerging Technologies*, *85*, 211–233. https://doi.org/10.1016/j.trc.2017.09.002

Zhuang, H., Feng, L., Wen, C., Peng, Q., & Tang, Q. (2016a). High-Speed Railway Train Timetable Conflict Prediction Based on Fuzzy Temporal Knowledge Reasoning. *Engineering*, *2*(3), 366–373. https://doi.org/10.1016/J.ENG.2016.03.019

Zhuang, H., Feng, L., Wen, C., Peng, Q., & Tang, Q. (2016b). High-Speed Railway Train Timetable Conflict Prediction Based on Fuzzy Temporal Knowledge Reasoning. *Engineering*, *2*(3), 366–373. https://doi.org/10.1016/J.ENG.2016.03.019

Zwaneveld, P. J., Kroon, L. G., Romeijn, H. E., Salomon, M., Dauzère-Pérès, S., van Hoesel, S. P. M., & Ambergen, H. W. (1996). INFORMS Routing Trains Through Railway Stations: Model Formulation and Algorithms. In *Source: Transportation Science* (Vol. 30, Issue 3). http://www.jstor.orgURL:http://www.jstor.org/stable/25768723