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Intelligent Rescheduling Trains for Air Pollution Management

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***Abstract*—**Optimization of timetable is the need of the day for the rescheduling and routing of trains in real time. Trains are scheduled in parallel with the road transport vehicles to the same destination. As the number of trains is restricted due to single track, customers usually opt for road transport to use frequently. The air pollution increases as the density of vehicles on road transport is increased. Use of an alternate mode of transport like train helps in reducing air-pollution. This paper mainly aims at attracting the passengers to Train transport by proper rescheduling of trains using hybrid of stop-skip algorithm and iterative convex programming algorithm. Rescheduling of train bi-directionally is achieved on a single track with dynamic dual time and varying stops. Introduction of more trains attract customers to use rail transport frequently, thereby decreasing the pollution. The results are simulated using Network Simulator (NS-2).

***Keywords*—**Air pollution, routing protocol, network simulator, rescheduling.

I. Introduction

NOWADAYS, everywhere in the urban area, traffic and pollution is increasing at a high rate by using road transport. Also, climate change, global greenhouse gas (GHG) emissions due to human activities have grown with an increase of 70%, among which CO_2 is the main cause for it.

About 90% of air pollution is reported due to road transport, out of which 72% is contributed by CO_2, and in rail, diesel emission contribution is 0.6% as shown in Fig. 1.

An alternate solution is hence required to reduce the air pollution. In comparison with any other transport mode like road or air, railway transport contributes 3-10 times less CO_2 emission [1]. Other than CO_2, NO_X and P M_{10} also give rise to air pollution. Emission of NO_X and P M_{10} is lesser by train than car and plane as shown in Fig. 2.

Railway transport not only reduces air pollution, but also it contributes 2-5 times more energy efficient mode of communication than road, shipping and aviation.

The three divisions of working in railway system are:

1) Control Management Layer.
2) Safety Management Layer.
3) Traffic Management Layer.

Traffic Management Layer Indirect control of signaling is responsible for timetabling, customer information, train data, and rail information system. Control Management Layer Direct control of signaling is responsible for configuring routers, tracking the location of trains, and automatic control operation of trains. Safety Management Layer responsible for giving protection through the use of signals includes fire extinguisher, explosives, obstacle detection, and collision avoidance [9].

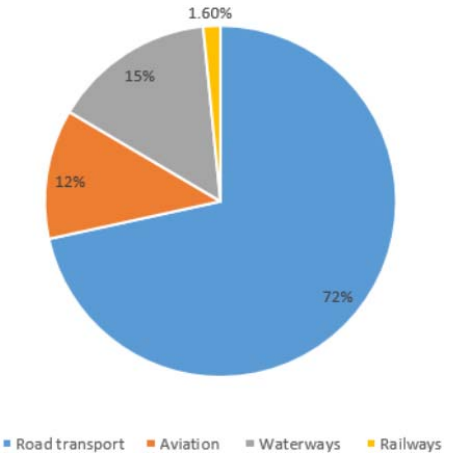


Fig. 1 CO_2 Emissions 2005 in U-27 by sector and transport mode

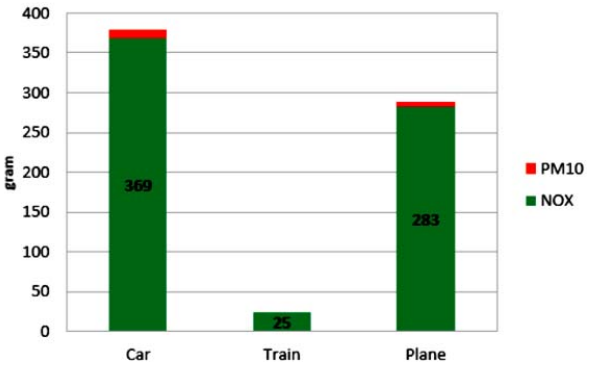


Fig. 2 NOX and P M_{10} emission by car, plane and train

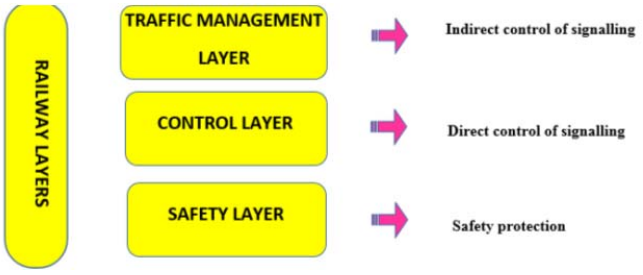


Fig. 3 Schematic diagrams of railway layer

II. Related Work

Isaai and Singh [3] presented a constraint based heuristic technique to reduce total waiting time by introducing a look-ahead constraint based algorithm for predictive scheduling of

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passenger trains on a single-track railway with some double-track parts. Simulation experiments with real data show the superiority of the schedules created to those by human experts with reference to data provided from predictive timetables and specifications of Iran Railways.

Sun et al. [4] proposed a travel time model by reconstructing a typical Mass Rapid Transit (MRT) trip into segments. Based on the regression results, a location estimation model was developed to distinguish between passengers travelling on trains and waiting on platforms.

Zaninotto et al. [6] presented a new formulation of single-track train scheduling problem assuming fixed travel time and variable dwell time for dispatching trains during operations. The computational result shows that branch and bound scheduling algorithm for optimal train scheduling is very useful to limit delay propagation dealing with any kind of disturbed traffic situation. The train ordering decisions are taken at each station in both traffic directions. However, the use of train re-routing algorithm is suggested only in the heterogeneous time-table. The overtaking between trains is favorable for travelling in the same direction with different speeds. Furthermore, re-routing gives significantly better quality solutions to re-optimized train orders.

Xu et al. [7] proposed a heuristic and low complexity algorithm to address the challenge of huge complexity of Markov Decision Problem (MDP) problems. Delay-aware fair downlink scheduling with heterogeneous packet arrivals and delay requirements for a relay-assisted high-speed railway (HSR) network are considered. The problem was modeled as an infinite-horizon average reward "Constrained Markov Decision Problem" (CMDP). The data arrival process and the channel process are Markovian. Simulation result shows that the proposed algorithm outperforms the other existing schemes in terms of average weighted delay performance and user fairness.

Yue et al. [8] proposed a model based on microscopic devices of railway infrastructure, such as tracks, switches, and crosses. For computing maximum profit of operation plan without any conflict, the scheduling decision is made on the basis of discretized resource time network and Lagrangian based Heuristic method.

Sama et al. [10] proposed a Fast Scheduling and Routing Metaheuristics Algorithm for railway traffic control in busy networks focusing on the efficient control of strong traffic disturbances (such as multiple train delays and temporarily unavailable block sections). Design of effective metaheuristics is based on a problem decomposition into train scheduling and routing decisions is the main consideration. The metaheuristic algorithms were compared on a complex network with dense traffic flows, and the variable neighborhood search algorithm was found to compute faster and so it is the new best known solutions for some CDR instances.

Wang et al. [11] proposed a new Iterative Convex Programming (ICP) to solve the train scheduling problem by comparing the performance of ICP approach with the other alternative approaches like non-linear programming approach, a mixed-integer non-linear programming (MINLP) approach, and a mixed integer linear programming approach. Also, it deals with real-time train scheduling problem with stop-skipping and shows to solve it using an MINLP and MILP approach.

III. AD HOC On-Demand Distance Vector (AODV)

A. Path Discovery

The path discovery process starts with the need of source node to communicate with another node that does not contain routing information in the table. Each node maintains two different counters: a node sequence number and a broadcast ID. The source nodes initiates path discovery by broadcasting a Route Request (RREQ) packet to its neighbor. The RREQ holds the following fields: Source Adder, Source Sequence, Broadcast ID, Destination Adder, Destination Sequence, Hop-Count. Broadcast ID is incremented whenever the source advertises an RREQ. Each neighboring node sends a reply by sending a route reply packet (RREP) or re-broadcast the RREQ packet by incrementing the hop count to their neighbor. An RREP packet contains the following fields: Destination IP address, Source IP address, Broadcast ID, Expiration time for reverse path route entry, and Source nodes sequence number [2].

B. Reverse and Forward Path Setup

The source sequence number is used to maintain new information about the reverse route to the source and the destination sequence number states to route the destination before it can be accepted by the source. As the RREQ travels from a source to various destinations, it sets up the reverse path from all nodes back to the source. Finally, a RREQ will arrive at a node (maybe the destination itself) that possesses a current route to the destination. If a node does not find a current route to the destination or the RREQ has not been processed before, then the node unicasts a RREP to its neighboring node from which it received the RREQ [12].

C. Route Maintenance

Source nodes reinitiate the route discovery during an active session to establish a new route to the destination. Special RREP is sent to the source node for the movement of destination node or other intermediate nodes. Sending of periodic hello messages ensures symmetric links as well as detection of link failure. The node upstream propagates an unrequested RREP with a new sequence number and hop count of 1 to all active upstream neighbor in the case where hop becomes unreachable [13].

IV. Proposed Work

A. Effect of Air Pollution on Agriculture

Air pollution affects human being and plant equally. The effects of air pollution on plants are developing day by day, which means that it cannot be treated in one day. Farmers mainly focus on addressing challenges of pests and diseases practices, yet a major challenge of air pollution is left behind. Crops can get defected on exposure to high concentrations of

various air pollutants. The effect on plants can be noticed by visible markings on crop leaves, reduced growth leading premature death of plants.

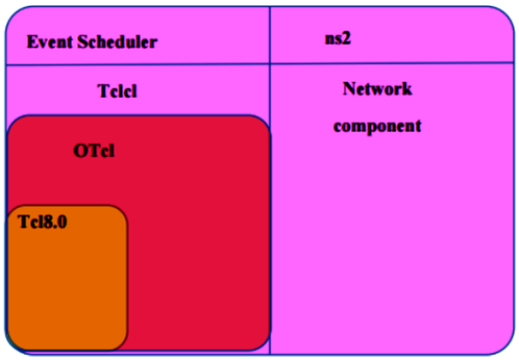


Fig. 4 Architectural view of NS2

Air pollution is mainly a problem of urban and industrial areas in the developed nations; however, in the last three decades, changes in the pattern of air pollutant emissions, including increases in the road vehicles have increased the impact of air pollutants in rural areas too. The rapid increase in the use of road transport has caused the adverse effect on agriculture in many parts of the world. The pollution caused by road transport can be minimized with the use of railway transport. The survey above showed that the rail transport contributes lesser air pollution. The present paper focuses to encourage the use of railways by rescheduling. Two algorithms are evaluated for the re-scheduling of train, among which:

1) Stop skipping algorithm
2) Iterative convex programming algorithm are the most common.

B. Stop-Skipping Algorithm

Real time problem is fixed by stop-skipping algorithm such that the stations to be skipped are defined initially. Passengers will never reach their destination under skip stop method.

C. Iterative Convex Programming Algorithm

Computation time is kept high, and the dwell time is fixed. Train waits for same amount of time at the station whether passenger is waiting for the train or not.

D. Proposed Algorithm

1) Hybrid of Stop-Skipping and Iterative Convex Programming

Train scheduling is done in such a way that stop or skipping of trains is decided based on time and stations so that performance is increased.

Departure time = arrival time + waiting time (not fixed) initial time t = 0 sec
Separate train whether it is from Bangalore and Mysore assign speed and destination to each train
In case of two trains approaching same station, priority is given to Bangalore express train
Keep track of number of trains reached destination (tr) increase t
iftr<= N , repeat step 2-7 (N = no of trains)
iftr> N then stop.

V. Simulation and Results

The proposed method is implemented using NS2 (network simulator) software. NS or the network simulator (also popularly called NS2) is an open source discrete event network simulator. NS2 has continuously gained tremendous interest from industry, academia, and government. NS is used in the simulation of routing protocols others and is heavily employed in ad-hoc networking research. NS2 supports popular network protocols, offering simulation results for wired and wireless networks alike [5].

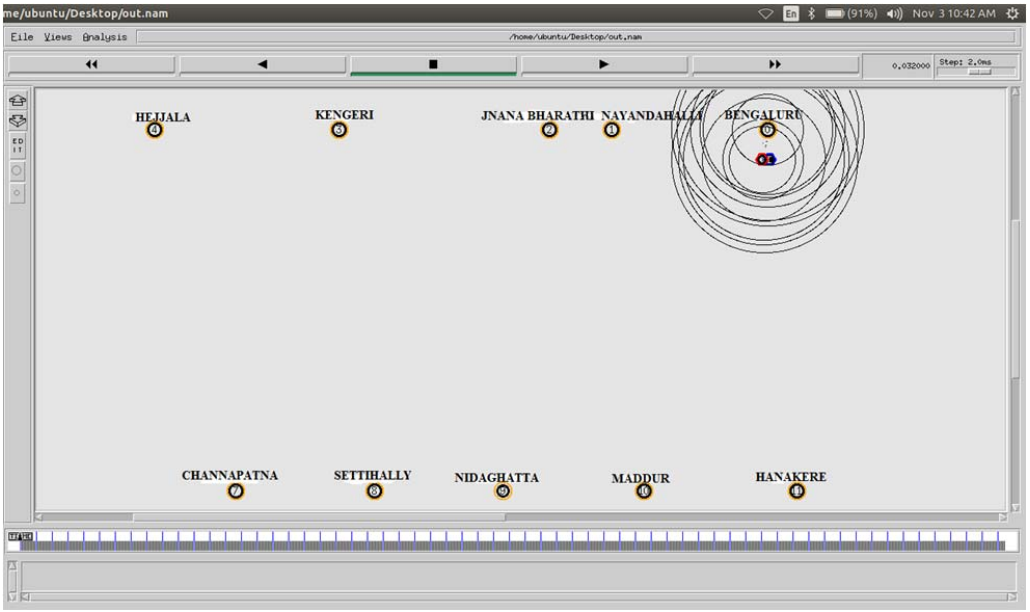


Fig. 5 Initial conditions

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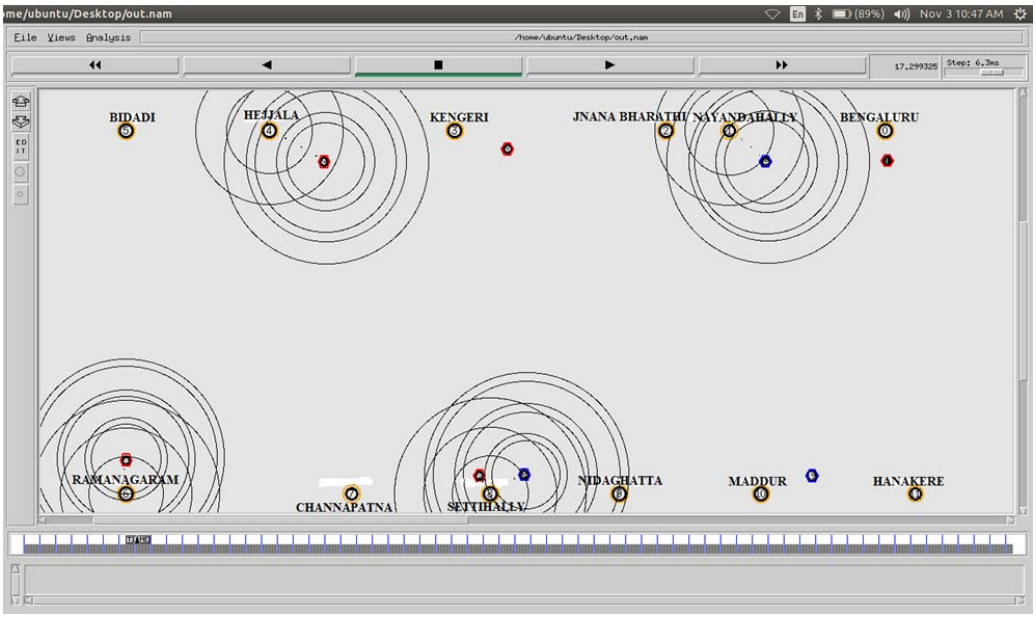


Fig. 6 Passenger and express train

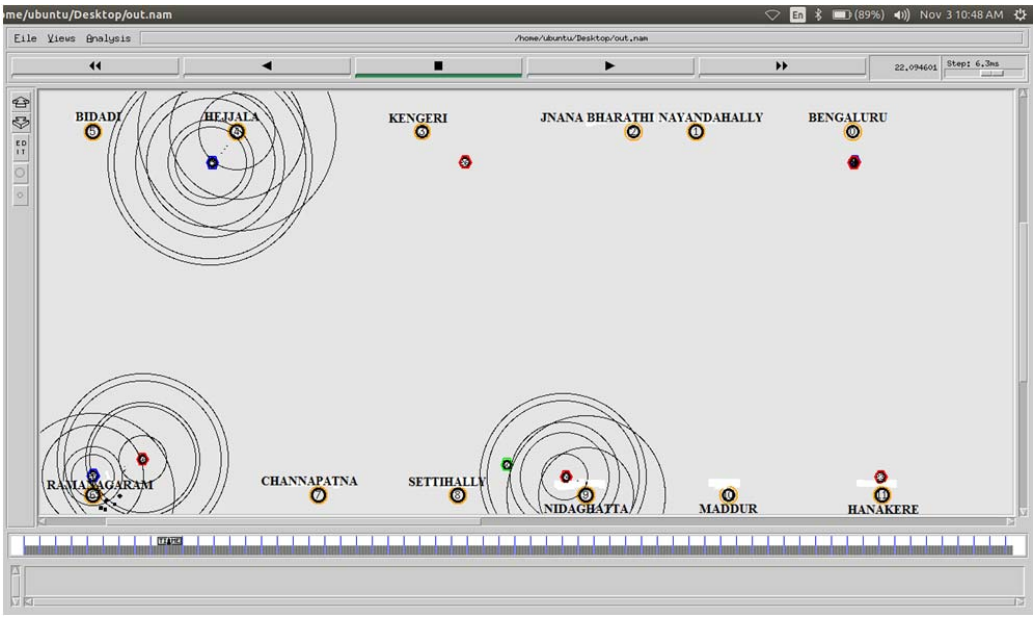


Fig. 7 Additional train and express train

A. Simulation Results

1) Initial Conditions

Nodes are created predicting as railway station.

Initially, time t= 0, at 4.00 AM. Red node indicates express train, blue node indicates passenger trains, and green node indicates additional train as illustrated in Fig. 5.

2) Express Train and Passenger Train Arriving at the Same Time

On arrival of express train from Bangalore and passenger train from Mysore at the same time, the information is sent to the station and passenger train to reschedule. Meanwhile, express train gets the signal to move forward as shown in Fig. 6.

3) Priority Given to Additional Express Train

In the case of two express trains, i.e. one regular express train and an additional express train, the priority is given to the additional express train as indicated by green colour in Fig. 7.

4) Priority to Bangalore Express

In the case of availability of other trains at the same time, priority is given to Bangalore express train as shown in Fig. 8.

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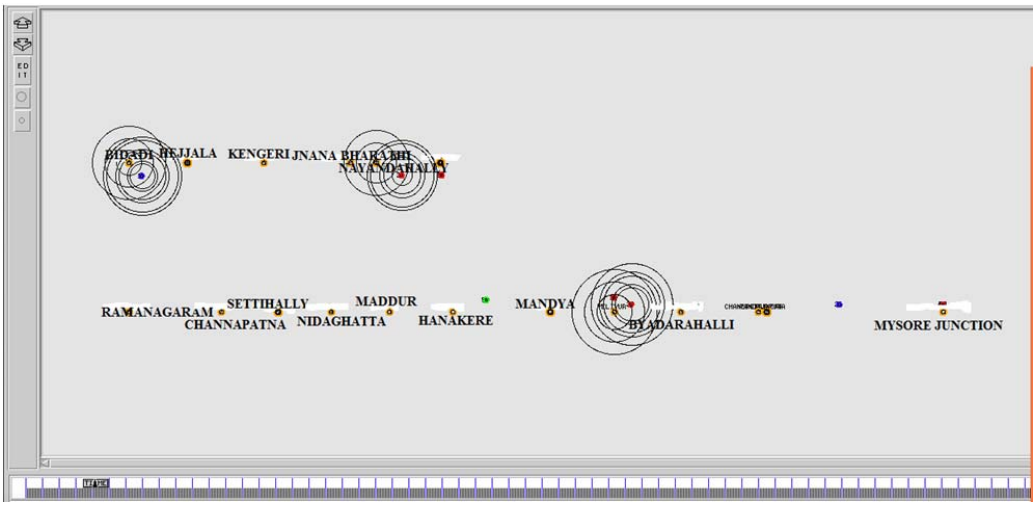


Fig. 8 Both express trains

TABLE I
COMPARISON OF EXISTING AND PROPOSED TRAVEL TIMING (BANGALORE-MYSORE)

Train Timing for Bangalore-Mysore	Existing Travel Time (Hour.Minute)	Proposed Travel Time (Hour.Minute)
Kavery Express	2.50	2.46
Bangalore-Mysore Passenger	3.30	3.20
Mysore Express	2.50	2.30
TiruparatiChamarajanagar Fast Passenger	3.0	4.55
Golgumbaz Express	2.5	2.5
Bangalore Mysore Passenger	3.10	3.0
Rajya Rani Express	2.45	2.28
Basava Express	2.35	2.33
Malgudi Express	3.10	3.0
Tippu Express	2.30	2.1
Chamundi Express	2.55	2.55
Bangalore Chamarajanagar Passenger	3.20	3.18
Karwar Express	2.40	2.3
Kavery Express	2.40	2.3
Mysore Night Queen Passenger	4.05	4.05
Six Additional Trains	Travel Time (Hour.Minute)	
Passenger 1	3.5	
Express1	2.4	
Express 2	2.38	
Express3	2.42	
Express 4	3.0	
Express 5	2.28	

VI. COMPARISON BETWEEN EXISTING TRAVEL TIME AND PROPOSED TRAVEL TIME

A. Bangalore-Mysore and Return Timing

Data for existing and proposed travel time of total 16 trains running between Bangalore to Mysore including six additional Trains, one passenger train and five express trains and their travel time are added. Since passenger train consumes more time to cover the distance, express trains are preferred to decrease the travelling time and increase the availability of trains as shown in Tables I and II.

TABLE II
COMPARISON OF EXISTING AND PROPOSED TRAVEL TIMING(MYSORE-BANGALORE)

Train Timing for Mysore-Bangalore	Existing Travel Time (Hour.Minute)	Proposed Travel Time (Hour.Minute)
Karwar Express	2.20	2.1
Bangalore-Mysore Passenger	3.10	2.5
Chamundi Express	2.45	2.4
Malgudi Express	2.10	2.0
Tippu Express	2.45	2.4
Basava Express	3.10	3.0
Bangalore-Mysore RajyaRani Express	2.40	2.3
Mysore-Bangalore Passenger	3.15	3.0
GolGumbaz Express	2.55	2.4
Mysore Mayuladuthurai Express	2.50	2.4
Mysore Tuticorn Express	3.15	3.1
Mysore Ajmer Express	3.15	3.1
Hampi Express	3.10	3.0
Mysore Bangalore Passenger	3.25	3.15
Kaveri Express	2.55	2.43
Karwar Express	2.55	2.43
Mysore Night Queen Passenger	4.05	4.0
Six Additional Trains	Travel Time (Hour.Minute)	
Passenger 1	3.55	
Express1	3.0	
Express 2	2.3	
Express3	2.38	
Express 4	2.55	
Express 5	2.41	

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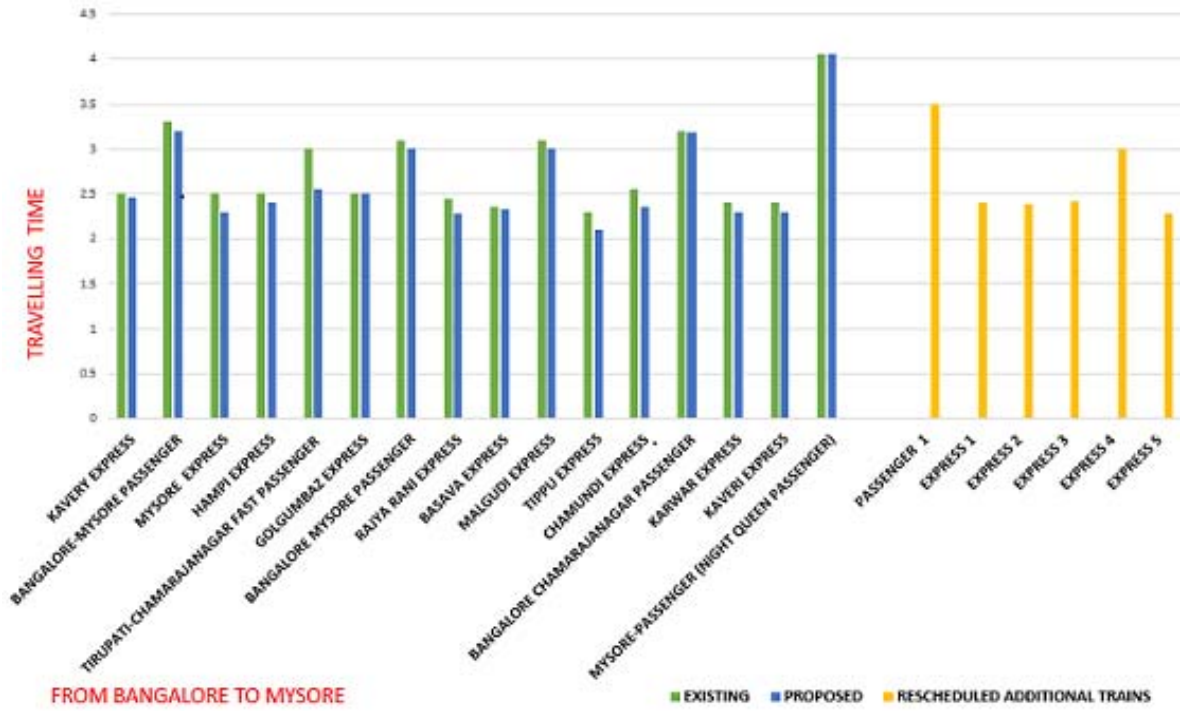


Fig. 9 Plots for train timing (Bangalore to Mysore) including additional trains

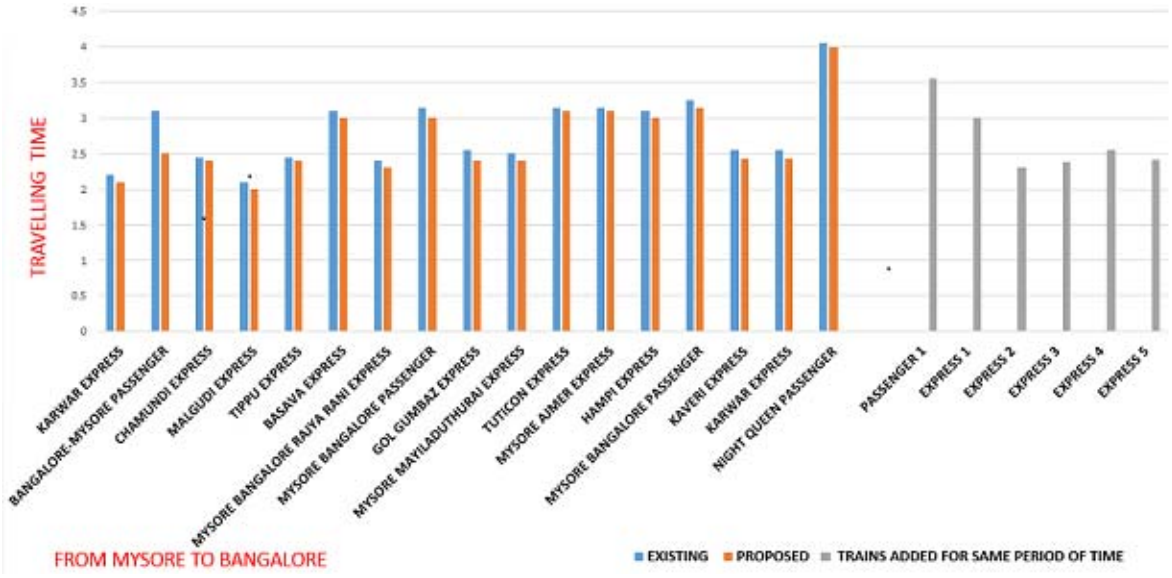


Fig. 10 Plots for train timing (Mysore to Bangalore) including additional trains

B. Graphs

Effectiveness of the proposed algorithm for reducing the travel time by increasing the frequency of additional trains to the passengers is shown Figs. 9 and 10. Additional trains are scheduled without affecting the rescheduled trains irrespective of trains between Bangalore to Mysore or Mysore to Bangalore, respectively.

VII. Conclusion

Road transport is the main cause of air pollution, which is not only affecting human health and environment but equally affecting agriculture by hindering growth and damaging crop yield. Hence, reducing air pollution is the biggest challenge. Switching to alternate mode of transport can bring down the level of air pollution. Among all the available modes of transport, rail transportation contributes to only 3% of air pollution, which is very less in comparison with the other modes. Using hybrid ICP and Stop-Skipping Algorithm for train transport is found to be very useful for rescheduling of trains. Real time train scheduling with a new approach by using hybrid ICP and Stop-Skipping methods is proposed to make the train travel more suitable for the passengers by

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reducing the travel time and increasing the availability of train.

The three scheduling approaches, Stop-Skipping approach, Iterative Convex Programming approach, and the proposed hybrid approach are compared, and the results conclude:

1) Stop-skipping approach has less travelling time.
2) Though ICP approach is iterative, its computation time is more.
3) The proposed hybrid approach can provide good trade-off between travelling time and computational time. Along with this, additional trains are scheduled bi-directionally on single track such a way that trains are available frequently. Since trains are available frequently, it attracts passenger to use train transport rather than road transport, reducing air pollution.

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