Transportation planning and Scheduling: A Literature Review

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Abstract: **The proficiency of public transport depends on different factors like resource availability, resource distribution and technology. This many a times leads to inaccessible, disorganized and unavailable public transport. In order to achieve proper resource allocation transport planning is necessary. Transit planning process spans over strategic, tactical and operational planning process. In this paper, we review the literature on transit planning process specially for Frequency setting, optimization and vehicle scheduling purpose.**

***Index Terms*-Frequency Optimization, Public Transport.**

I. INTRODUCTION

Transport provides a way of movement of human being, goods from one place to another. Passenger transport can be either public or private depending on the mode of transport which may be land, air or water. Amongst bus transit is the most common and heavily used system in India as it provides the cheapest way of travelling. In most of the Indian cities, buses are run under public-private ownership. Irregular bus timings, overcrowded buses and unavailability of public transport for some route at a specific time are the reasons which lead people to choose a private vehicle for transportation purpose. Increased private vehicle ownership has declined the use of public transport.

In order to encourage citizens to opt for public transport, there is a need to provide an accessible, affordable, efficient, reliable service for the mobility of people at the same time; agencies need to minimize the operational cost. In today's world demand for mobility is increasing, hence there is a need for an efficient public transport in order to reduce traffic congestion and pollution like issues. The Indian transportation sector has not been able to cater to the growing travel demand. Municipal public transport is always short of resources. In order to achieve the objectives like customer satisfaction, revenue generation and Reduction in operational cost the resource plays an important role from commuter as well as operating agency's perspective. Commuters require the frequent no. of the resources and operating agency need to minimize the available resources to reduce the infrastructure cost.

In order to increase revenue and reduce expenditure Municipal Corporation needs to optimize the resource utilization through various techniques to improve resource availability and reduce infrastructure cost. Fatima and Kumar [1] have outlined the public transit sector challenges ranging from technical to operational for Indian cities. The binary logit analysis is used to estimate the variation in modal shift behavior. In order to evaluate the proposed model Statistica and Biogeme environment were used. Log-likelihood was used to predict modal shift behavior. To evaluate the proposed system data was collected for the city of Bardoli, Gujarat, India. The results show that the proposed system significantly improved the current scenario of public transport.

Rohani et al. [2] reviewed different bus service types, operations and its quality as well as outlined the role of bus service provider and driver. Rojas et al. [3] explained the transit network planning process. It consists of five different stages: Transit Network Design, Frequency Setting, Transit Network Timetabling, Vehicle Scheduling and Crew Scheduling. The decisions taken at each stage can influence the decision that can be taken at subsequent stages of the planning process, depending on the context i.e. strategic, tactical or operational.

The paper is arranged in the following sections: Section II discusses the related work, Section III concludes the paper.

II. LITERATURE REVIEW

Transit planning process consist of five different steps: Network design, Frequency setting, Timetable scheduling, Vehicle scheduling and Crew scheduling. Researchers have studied various methods for transit network planning process. This study further can be grouped into following categories:

A. Transit Network Design

Transit network design is a strategic planning process. It helps in determining the number of lines or routes and no. of intermediate stops required for a particular network.

Guihaire and Hao [4] outlined the analysis of various approaches dealing with strategic and tactical planning stages of network design and scheduling. Authors also reviewed different mathematical, heuristic and evolutionary approaches dealing with design, frequency setting and timetable setting problems.

Schobel [5] explained various transit network design models like cost oriented, passenger-oriented, game-theoretic and location based models as well as outlined various mathematical approaches and algorithms used for line planning purpose.

1) *Heuristic approach in transit network design:*

Nikolic and Teodorovic [6] proposed swarm intelligence based Bee colony optimization approach for transit network design purpose. In order to measure the system performance the set of parameters used are the percentage of demand satisfied without any transfer, with one transfer, with two transfer, the percentage of demand unsatisfied and

average travel time for four different scenarios: four routes, six routes, seven routes and eight routes in each route set. As a future challenge system needs to be tested against multiple path passengers' assignment among transit route. Bielli et al. [7] proposed stochastic and random search technique and genetic algorithm based heuristic approach for transit network design and optimization purpose respectively. The approach has been applied to the city network of Parma in the middle-north of Italy. As a future work neural network or n-best solution container can be applied for fitness function evaluation.

B. Frequency Setting and optimization

Frequency setting is tactical planning process, it depends on the decision taken at strategic planning phase. No. of lines and no. of intermediate stops, the output of transit network design phase impacts the decision taken at frequency setting phase of transit planning process. Researchers have studied various methods for frequency optimization purpose in public transit. Optimization models have been proposed in terms of vehicle cost, capacity and frequency optimization.

1) *Frequency Setting:*

In order to improve the available bus service there is a need to reduce the number of transfers and total travel time for an operator and the user respectively. Szeto and Wu[8] addressed the problem of a trunk bus route design and frequency setting problem for a suburban residential area in Hong-Kong. A genetic algorithm and neighborhood search heuristic have been used for the network design and frequency setting purpose. In order to improve the effectiveness of the solution two crossover and four mutation operations were performed. A hamming distance based diversity control mechanism is used to tackle the route search problem. The performance measures are reduction in number of transfers and total travel time.

Verbas and Mahmassani [9] [10] authors addressed the problem of frequency setting and introduced the two non- linear optimization formulations for ridership and waiting time saving maximization and net cost minimization. Headway acts as decision variable in both formulation patterns. Thelimitation is that the parameter bus size is a fixed variable rather than decision variable.

Gkiotsalitis and Cats [11] provided a solution method for frequency setting problem that uses Branch and Bound and sequential quadratic programming method. The problem was formulated as a non-linear discrete problem. The proposed approach was tested using data collected from seventeen central bus lines in Stockholm. The performance of the system is evaluated using accuracy and sensitivity. The limitations of the system are AVL data availability, the method determines frequency separately for each lines hence no interlining and no capacity constraints were considered.

2) *Frequency Optimization:*

The frequency optimization problem aims at determining the time interval between successive buses for a given transportation line. Luhua et al. [12] authors have addressed the problem of bus service frequency optimization model in terms of minimization of expenses paid by passengers and bus operators as the target of optimization model. Authors have proposed an improved genetic algorithm for optimization purpose and same is illustrated with an example of two buses i.e. Bus No.6 and. Bus No.9 in Changchun City, China. The performance of the model is compared on the basis of departure time interval, total expenses paid by passengers transfer, total expenses of public transit companies with existing model. The outcome shows that the optimization model performs better than existing system.

Martnez et al.[13] authors have proposed a frequency optimization model in order to determine the time interval between successive buses on the line(route). The proposed model uses a non-linear bi-level formula based mixed integer linear programming (MILP) method and a metaheuristic approach called Tabu Search for solving smaller and larger instances respectively. The evaluation of the proposed model is performed using two test cases, those are a city of Rivera, Uruguay and Montevideo, capital of Uruguay. An assumption that the bus has sufficient capacity to carry the desired number of passengers may not be always true in a real life scenario.

Giesen et al.[14] [15] proposed a heuristic based solution approach for multi-objective transit frequency optimization problem, multi-objective variant of MILP and Tabu search techniques are used. Authors have considered two conflicting objectives namely minimization of users' total travel time and fleet size and proposed methodology has been applied to a real time data of Puerto Montt, Chile.

Arizti et al.[16] addressed the problem of determining the time interval between successive buses for a public transport line and proposed a bi-level formulation which is then transformed into mixed integer linear programming (MILP) used for solving small-sized city instances. Huang et al. [17] addressed the problem of determining optimal bus frequencies by applying bi-level model. Genetic algorithm is used to determine bus frequencies under uncertain demand and evaluated for deter- mining optimal bus frequencies for the city of Liupanshui, China. Sensitivity analysis is used to evaluate the system performance. As a future scope analytical method can be used to obtain optimal frequencies under congested transit network

C. *Vehicle Scheduling*

Vehicle scheduling is an operational planning process. The results obtained from frequency setting phase are considered as input to the vehicle scheduling process.

As explained in Hafezi et al. [18] frequency, reliability, capacity, cost and safety are the performance characteristics for bus service, among them frequency and capacity are the important one from Bus authority perspective. Authors have reviewed various bus scheduling model for peak-hour and non- peak hour timing buses. Gkiotsalitis and Kumar [19] addressed the public transport timetabling problem in order to reduce excess waiting time of passengers. To generate

timetables and bus schedules data was gathered Using AVL technique from the running vehicles. For evaluation purpose, the timetable of the bidirectional bus line in northern Europe is considered.

Wagale et al. [20] proposed a Demand and Travel time Responsive (DTR) model to optimize bus schedules in terms of cost and frequency. The proposed model is evaluated using the case study of Jaipur city, India. Sensitivity analysis is used for performance evaluation purpose. The model uses segment-stop based micro data. The system fails in constructing a timetable for stops which require longer riding times. A stochastic optimization model was proposed by Naumann et al. [21] for robust vehicle scheduling purpose. In order to illustrate the proposed model instances of German cities with network layer and service trips are used. The main limitation of the model is it cannot solve the larger city instances within a reasonable amount of time. An evolutionary algorithm is used for timetable optimization model in order to reduce the waiting time of passengers.

Tong et al. [22] Proposed an optimization model based on network flow to optimize vehicle capacity and bus routing to satisfy user demands. In order to develop a solution algorithm, Lagrangian decomposition method is used and to reduce the solution search space a space-time prism based method is used. In order to evaluate the model, the case studies of Sioux Falls network and Beijing transportation network have been conducted for illustrative and real-world large-scale transit network. The assumption, regarding passenger demand, sinks to provide good results. Sensitivity is used as a measure to evaluate the system performance. Kidwi et al. [23] developed evolutionary algorithm based optimization model for vehicle scheduling purpose. Proposed solution approach consist of two phases: In first phase Bus allocation is done on individual route and in second phase no. of buses are reduced on network basis.

Zuo et al. [24] developed genetic algorithm based solution for vehicle scheduling purpose. As far as the weighting of multiple and conflicting objectives is concerned single- objective optimization approach combines all objectives and assigns weight as single objective. Hence in order to satisfy multi-objective criteria authors have presented a methodology, it generates a set of Pareto solutions, from which multiple block subset were selected by applying multi-objective genetic algorithm. The proposed methodology was tested for a bus line in Nanjing, China. Wang and lin [25] Proposed greedy heuristic based divide-and-conquer technique to solve multiple-depot vehicle scheduling problem. It aims at assignment of vehicles to serve a given no. of trips. The methodology was tested on data collected from Kinmen Bus Administration. The results demonstrate that the algorithm is effective in solving multiple- depot vehicle scheduling problem

III. CONCLUSION

In this paper we present the literature review of the approaches used for Transit network design, frequency setting and optimization and vehicle scheduling purpose. A good amount of work is done in transportation planning process still there are chances to improve the system by integrating two or more problems. The techniques discussed herein for planning phases of transport deal with mostly Operations Research techniques. Very few authors have tackled the problem like optimization of resource utilization .In order to improve the Transit system efficiency Machine Learning techniques may help.

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TABLE 1: PAPERS DEALING WITH STRATEGIC AND TACTICAL PLANNING STAGES OF TRANSIT PLANNING PROCESS

Reference	Problem Addressed	Technological approach	Case study	Objective Function
Nikolic and Teodorovic [6]	Network Design	Bee Colony ptimization Metaheuristic	--	--
Bielli et al. [7]	Network Optimization	Genetic Algorithm	City network of Parma middle-north of Italy	--
Szeto and Wu [8]	Route Design and Frequency Setting	Genetic Algorithm and Neighborhood search heuristic	Tin Shui Wai, Hong Kong	--
Verbas and Mahmassani[10]	Frequency optimization	Non-linear optimization	--	Maximize no. of riders+ saving of total waiting time Minimize the net cost
Martinez et al.[13]	Frequency Optimization	Mixed Integer Linear Programming and Tabu Search	City of Rivera, Uruguay and Montevideo, capital city of Uruguay	Minimization of sum of on board travel time+waiting time
Giesen et al. [14]	Multi-objective frequency Optimization	Genetic Algorithm	City bus network of Puerto-Montt, Chile	Minimize travel time + fleet size
Arizti et al. [16]	Frequency optimization	Bilevel and Mixed Integer Linear Programming	--	Time interval between subsequent buses
Huang et al.[17]	Frequency optimization	Bilevel model approach and Genetic Algorithm	Bus network of city of Liupanshui, China	Minimization of expected travel cost of all passengers
Wagale et al.[20]	Bus Schedule optimization	Demand and Travel time responsive (DTR) model	Case study of Jaipur city, India	Time interval between subsequent buses
Naumann et al.[21]	Vehicle Scheduling	Stochastic programming approach	Instances of of small-sized German cities	Minimization of expected sum of planned cost+ costs caused by disruption
Tong et al. [22]	Optimization of passenger-to-vehicle assignment and vehicle routing	Lagrangian decomposition and space-time prism based method	Sioux Falls network and Beijing metropolitan area transit network	Optimization of vehicle capacity utilization
Kidwai et al. [23]	Bus Schedule optimization	Genetic Algorithm	City of Burdwan, West Bengal, India	Minimization of frequency of buses and Fleet size
Zuo et al.[24]	Vehicle Scheduling	Multiobjective Genetic Algorithm and DTAP	Bus network of Nanjing, China	--
Wang and Lin[25]	Multiple depot vehicle scheduling	Greedy heuristic algorithm based on divide-and-conquer	kinmen Bus Administration	--