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OPTIMIZATION OF BUS TRANSIT SERVICES- REVIEW

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Abstract — *Growth of population, increasing employment opportunity and general trend of development towards metropolitan cities results urbanization. Limited space available in the already planned cities and urbanization avail various transportation experts for optimization of mass transportation. To minimize various transportation problems available transportation services must be reviewed periodically for the mobility of the population with feasibility. Periodic review of the existing public transportation system imparts maximum efficiency. Various researchers have made optimization of bus transportation services avail for the mass transportation. The basic aim of optimization is to provide best services to the road user with highest possible degree of safety, comfort and minimum time utilizing various advanced techniques and strategies which can be utilized to satisfy transportation demand of society as well as reduction of transportation problems in a great extent. In the present study the pioneer's research work done in route optimization is referred and various aspects taken into consideration is highlighted. It is observed and concluded that selection of routes is required considerable skill and knowledge, the selection of attributes for the each case may be different and criteria of selection discussed for ready reference.*

Keywords- *Urbanization; Optimization; Transit*

I. INTRODUCTION

India is the second largest country in the population after China. Rapid growth of population creates so many problems in the era of physical resources for human life for any developing nation. Despite of basic human needs and employment opportunities in metropolitan cities creates urbanization. As a result of urbanization day by day traffic problems are becoming severe in metropolitan cities for the road user, society as well as to the government. Problems of traffic congestion increasing rapidly. If these traffic congestion problems are not resolved timely the numbers of severe accidents may increased rapidly .

To overcome and reduce the problems of traffic and to handle the severe traffic situation it becomes essential for society to increase utilization of mass transportation system. Various kinds of mass transportation system are the best solution for the society which provides highest mobility to a larger area of population with minimum cost. In order to increase the utilization of public transportation system, planning as well as the services of the mass transportation must be better than private transport system and must be reviewed periodically according to the needs of the society and availability of resources.

The basic aim of efficient public transport system is to satisfy the demands of the population and to increase the operator's profit. To achieve the goal the optimization, proper scheduling, suitability of route and periodic reviewing of the system is required at designing as well as implementing stages of the transportation system.

With advancement of technology as well as availability of various computer software transportation problems can be solved up to great extent by developing Mathematical models, Simulation of transportation problem, Use of Genetic Algorithm and Global Positioning System

Due to balancing and effective utilization of various public transport system and optimizing routes based on various performance indicators on the basis of research studies reduces many of the transportation problems such as

- Saving in travel time
- Reduction in fuel consumption
- Increasing mobility
- Saving in travel cost
- Reducing congestion problems
- Reducing environmental pollution
- Reduction in numbers of accidents
- Reduction in parking problems
- Increase in National income

All above direct and indirect benefits are the achievements due to effective utilization and implementation of mass transit system, which reflects development polices of nation according to budgetary provision.

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II. THEORETICAL BACKGROUND

Optimization is about formulating a mathematical model of a real problem and with the help from this model try to find the best solution to the problem with the definite condition.

TERMINOLOGY-:

Distance Travelled: Length of the route between two nodes in kilometers. (stations).

Direct Demand Satisfied: Demand directly satisfied by each node on route directly without any transfer station.

Indirect Demand Satisfied: Demand satisfied by each node on route with one or more transfer station.

Passenger Per Kilometer: It is the ratio of the demand of the passenger on particular route to the distance travelled between two routes.

Passenger –Kilometer: It is the multiplication of the no of the passenger on particular route to the distance travelled between two routes.

Link Density: It is the ratio of flow of the buses on the particular link to the length of that particular link between two nodes (stations)

Average Link Density: It is the ratio of summation of all available or considered link densities taken into consideration for design to the number of total links

Link Utilization: Link utilization indicates the utilization of link with respect to maximum flow on that particular link. It is defined as the ratio of the link flow to the maximum flow.

Route Utilization Coefficient :

R.U.C.=(Σ fi X li)/ (f max X Σli)

fi =Flow on link i ; li = Length of link i ;f max = Maximum link flow ; n = Total number of links in the route

Desired number of Buses : The absolute minimum of buses required on the route for the given level of service. The maximum of two values N_1 and N_2 calculated is taken as number of bus trips required on the route and hence maximum number of buses required.

N_1 = Maximum link flow on the route/ (Bus capacity X Over loading factor)

N_2 = Average link flow on the route/ Bus capacity

Where time period is the time in minutes for which data is surveyed or collected for analysis and route optimization is to be made.

Round Trip Time: It is the total time in minutes for which the bus takes to travel the route and lay over time

Maximum Number of Buses: It is the maximum number of buses feasible to serve the demand. The maximum number of buses can be calculated from following equation

Maximum Number of Buses= (N_3/Time Period)/ Round Trip Time

Where N_3 = Maximum trips required for the route defined as ratio of maximum link flow to bus capacity.

Desire Headway: This is the time headway in minutes. It is the desired number of buses ply along the routes defined as (Route trip time +Lay over time)/ No. desires buses

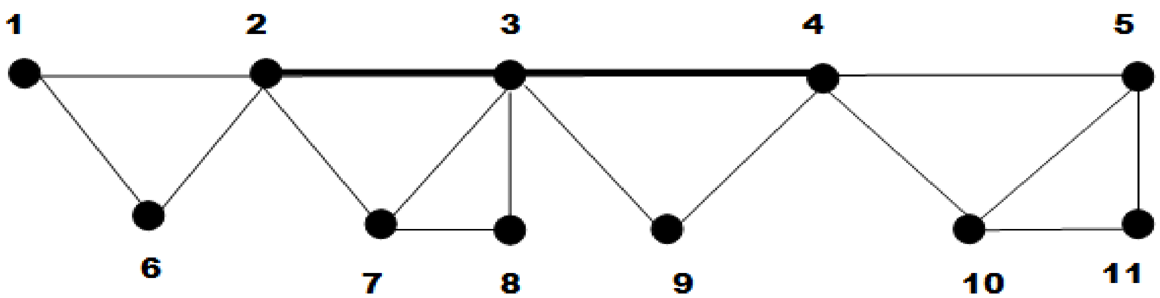
Minimum Headway: This is the time headway in minutes. It is the maximum number of buses ply along the routes.

Waiting Time : It is the passenger waiting time along the route i . It can be calculated as = (0.5) X (Headway) X (Demand satisfied along route)

Transfer Time: It is the time elapse at transferring point where passengers transfer from one node (station) point to another node (station) point.

Operating Distance: It is the total distance in kilometer travelled by the buses along the designated route.

Overlapping Route: The interaction of overlapping route is quite important for scheduling and satisfying the demands.



If the route 1-2-3-4-5 is selected route and the second selected route is 6-2-3-4-10-11 then the index of section 2-3-4 is marked twice for the OD pair of 2-3 , 3-4 and 2-4 . The demand of OD pair is equally distributed among these two routes The whole **optimization process** consist following **phases**

- Generating candidature route
- Route Optimization Phase
- Optimization Scheduling
- Route Scheduling optimization

Route Optimization of mass transit system is made considering following **criteria**

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- Route Length
- Minimum no of stops along a Route
- Non Linear Coefficient (i.e. Reflection of operation efficiency and operation cost in perspective of operator as well as travel time)
- Non Transfer Coefficient (i.e. Indicator of convenience of network)
- Stop Coverage (i.e. Represent potential travel demand within certain service area of bus stop)
- Flow of passengers per km along a route
- Route Efficiency (i.e. Balancing production and Attraction of route)
- Network Density (i.e. Indicator for evaluating the convenience of route for road user to access)
- Route Overlapping Coefficient (Indicate traffic jam condition)

Depending upon the traffic situation and route network a mathematical model is developed considering the above criteria for transportation route optimization problems.

BUS TRANSIT PLANNING PROCESS:

The design and operation of any bus transit services involve many complicated surveys and decisions. The main problem of designing bus transit service is to cover the maximum area under service and particularly to determine maximum farthest outward to extend transit route into low density suburb considering both operator cost and passenger impedance. The design of route and frequency of the buses indicate system performance from both operator and user point of view. According to Ceder and Wilson (1986) the bus planning process consist five stages.

INPUT	ACTIVITY	OUTPUT
	LEVEL-A	
DEMAND DATA SUPPLY DATA ROUTE PERFORMANCE →	NETWORK DESIGN →	CHANGE IN ROUTE NEW ROUTES OPERATING STRATEGIES
	LEVEL-B	
BUSES AVAILABLE SERVICE POLICIES →	SETTING FREQUENCIES →	SERVICE FREQUENCIES
	LEVEL-C	
DEMAND BY TIME OF DAY RUNNING TIME TIME FIRST AND LAST TRIP →	TIME TABLE DEVELOPMENT →	TRIP DEPARTURE TIME TRIP ARRIVAL TIME
	LEVEL-D	
RECOVERY TIME SCHEDULE CONSTRAINT COST STRUCTURE →	BUS SCHEDULING →	BUS SCHEDULE
	LEVEL-E	
DRIVER WORK RULE DRIVER SHIFT DRIVER PAYMENT →	DRIVER SCHEDULING →	DRIVER SCHEDULING

COMPLEXITIES OF BUS ROUTING AND SCHEDULING PROCESS:

The various constraints as well as various complexities in designing bus routing and scheduling are follows:

- Identification of nodes (stations) and stoppage stations (transfer stations)
- Selection of available path (routes) and Path restrictions
- The lay over time i.e. the amount of time between two successive trips made by vehicle
- The presence and capacity of variety of depot where vehicle may be housed.
- Constraints on the length of time a vehicle may be in service before it must reach the node station and given a rest period.
- Operator's financial constraints that put upper limit to the number of buses to be used.
- Operators service constraints that put upper limit to the number of buses to be used.
- Decision making process for the overlapping routes where the optimal number of buses to be used
- Number of depot
- Level of service
- Bus capacity –maximum and minimum load factor and Peak hour and off peak hour demand

III. LITERATURE REVIEW

Researchers have done a lot of related researches on the optimization of bus transit services and attained good outcomes with fruitful results.

Liping Fu, et al. (1857) developed "Real Time Optimization Model for Dynamic Scheduling of Transit Operations". They formulated a non linear programming problem with objectives of minimizing the total cost for both operator and passenger and formed route model using Global Positioning System (GPS) and performed sensitivity analysis using real

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life example to identify the conditions under which the proposed operating strategy is most advantageous. To maximize the potential of proposed strategy more accurate prediction model was suggested to be developed to take advantage of real time information on bus location, travel time and passenger count. A new bus control strategy was proposed in which stop skipping is applied to every other bus dispatched from the terminal. Stop skipping control is effective strategy to improve transit service quality and operating efficiency reducing waiting time, satisfying passenger demand and short headway.

Jan Owen Jansson (1980) analyzed "Simple Bus Line Model for Optimization of Service Frequency and Bus Size". He studied the effect of same number of buses in peak and off peak hours. He also studied the effect of optimal bus size , bus cost and other various contrasts on operating cost and profit. He explored consequences of including certain social costs such as waiting, riding in the analysis of bus operations. Using a simple model of bus line he derived optimal frequency of services (Bus flow per hour) by "Square root formula".

Lazar N Spasovic, et al. (1993) developed "Methodological Framework for Optimizing Bus Transit Service Coverage" extend radically outward from the Central Business District (CBD) serving rapid rail station. They developed optimization algorithm from an initial basic solution toward optimal solution and compared results based on route length and society welfare maximization. They performed sensitivity analysis to indicate how changes in the more importance exogenous parameters affect values of various decision variables (Route Length, Spacing, Headway Fare etc..) and Objective function(Corridor length, Passenger Density, Speed, Operator cost). They developed an equation for total hourly transit demand function and determined operator's cost maximizing operator's profit.

NJW van Zyl et al. (1999) analyzed "Public Transport Route Optimization Methodology in South Africa" They evaluate route optimization methodology and its need in South Africa. They applied DHV public transport route optimization model and compared route optimization result in three metropolitan area GPMC, KMC (Khayalami Metropolitan Council) and PEMET (Port Ellzabeth Metropolitan Transportation Area) in South Africa. The basic aim was to determine the potential for improving the road based public transport route network subject to existing rail network.

P.J.Gundaliya et al.(2001) developed mathematical model and fitness function using Genetic Algorithm to find optimal fleet size on an optimally designed routes . User cost was taken as total travel time, which includes in-vehicle travel time, waiting time and the transfer time. The operator cost was considered running time cost of the buses. The objective function was minimisation of summation of both costs. Constraint for load factor was taken for better level of service, fleet size constraint adopting to keep the number of buses under certain limit and link overloading constraint ensures that there cannot be buses over certain specified limit on any link. The Model developed was tested on the Mandl' s Swiss network of fifteen nodes. The results obtained by the model were compared with the Mandl and Baaj (1980) solution as the same network was used for analysis. They derived scheduling of buses with different ARFV (Average route flow value).; relation of total travel time per person with different ARFV (Average route flow value) and selection of ARFV value affecting the total travel time per person. They observed that Genetic Algorithm gives reasonably good values even with lesser pool size. However if pool size is increased results can be refined but it increases the computational time. It is observed that higher the value of ARFV higher the total travel time per person. However it is to be noted that time taken for solving the problem is not compared for the given network. The results have proved that simultaneous routing and scheduling using Genetic Algorithm for optimization has better edge over other existing approaches for routing and scheduling problems specially in the domain of Public Transportation.

Saravanan Dharma and Abd Manan Bin Ahmad (2005) analyzed "Optimization of Transportation Problem with Computer Aided Linear Programming". They developed a mathematical model considering three basic elements Source(s) ; Destination(s) and Weighted Edge(s). They solved transportation problem to find minimal cost path from source nodes to destination nodes and meet supply and demand constraints as a linear programming problem considering variable and constraints conditions.

Mukti Advani et al. (2005) made a research study on "Improvement in Transit Services Using GIS-A case Study of Bhavnagar State Transport Depot". They studied 49(forty nine) different routes from GIS and compared with length data from S T Department of Bhavnagar. Out of 49(forty nine) routes they optimized 45 (forty five) routes and 4 (four) routes were having routes length already less than the routes suggested by GIS. By route optimization and comparing distance S T Department , Bhavnagar save 20249 km route length and 3177 litre fuel saving.

Farhan Ahmad Kidwai et al. (2005) analyzed "A Genetic Algorithm based Bus Scheduling Optimization Model for Transit Network" of city of Burdwan, West Bengal ,India. They considered different levels of optimization to solve the problem

1. Minimum frequency of bus requirements for each route with guarantee of load or feasibility i.e. base fleet size is determined by considering individual route capacity
2. Fleet size of first level is taken as upper bound and fleet size is minimized by considering all routes together and using Genetic Algorithm.

The route design algorithm produced 81 (eighty one) feasible solutions considering different external user operator and external parameter for surrounding model.

Wel Fan and Randy B Machemehl (2006) formulated "Optimal Transit Route Network Design Problem with Variable Transit Demand: Genetic Algorithm Approach" using Genetic Algorithm. They prepared a model and proposed solution

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for the BTRNDP (Bus Transit Route Network Design Problem) with variable transit demand using Genetic Algorithm. They also formed generation procedure for initial candidate route set and network analysis procedure for the BTRNDP (Bus Transit Route Network Design Problem). They done sensitivity analysis considering effect of Population Size; Stopping Criteria; Crossover Probability; Mutation Probability ; Route set Size and Demand Aggregation.

Yiyo Kuo and Chi-Ming Luo (2011) proposed "Optimization of Circular type Routes for a Shuttle Bus Service suggesting Simulated Annealing (SA) algorithm to optimize the circular public transit route. They proposed a mathematical model to find the upper bound of the circular routing problem to maximize the quantity of passengers who can be serviced by buses within the same travel time limit.

Monyarth KOV et al. (2011) developed a new analytical model based on "Optimizing Frequency of Bus Services in Mixed Traffic Urban Streets". They found optimal frequency by maintaining equilibrium of flow of vehicle in mixed traffic and passenger flow on transit network using multi model equilibrium assignment with respect to frequency selected by Hooke-Jeeves algorithm. They analyzed a numerical example using Nguyen and Dupuis network to illustrate the operation of model and algorithm proposed in the paper. They also conducted sensitivity analysis in various directions to check performance and accuracy of proposed model. They analyzed Optimal frequency under increase of demand for various Origin Destination (O D) pair; Optimal frequency under variations of operating cost and Impact of bus vehicle capacity on setting of bus schedule, bus ridership and in vehicle travel time of Origin Destination (O D) pair.

Zachary Kurtz et al. (2011) analyzed optimization of Bus Rapid Transit Downtown to Oakland. They collected and studied data of 400+ buses with clever devices installed for 2009-10 and 2010-11 school year for Dwell time study (Dwell time refers the time the bus has its door open while servicing a bus stop .The Dwell time is generally 15% of the total time of a trip.) They studied factors influencing dwell time and effects of dwell time on speed of bus with respect to traffic. They analyzed bus bunching and its effect on arrival and redundant bus services.

Ivan Beker et al. (2012) suggested model based on "Shortest Path Algorithm as a tool for Inner Transportation Optimization" for forklifts routing optimization of items location in the ware houses using Dijkstra A, Floyd Warshall and Bellman algorithm and suggested different modes of route.

Patrick Jaillet and Jin Qi Melvyn Sim (2013) proposed general routing optimization model and developed two mathematical framework on "Routing Optimization with Deadlines Under Uncertainty" for a Linear decision rule formulation and a multi commodity flow formulation. They gave comparative study on the stochastic shortest path problem with dead line analyzing correlation between uncertain travel time to find optimal routing policies such that arrival time at nodes respect deadlines "As much as Possible". They introduce performance measure (lateness index) to evaluate deadline violation level of given policy for the network with multiple deadlines.

Partha Chakroborty analyzed optimal routing and scheduling in transportation using Genetic Algorithm to solve difficult optimization problem.(Case study –Bus routes for Vishakhapatnam road network). He subdivided the vehicle routing problem in subclasses for easy understanding as per field situation

Vehicle Routing Problem :TSP –Travelling Salesman Problem , In which single vehicle has to visit a set of node exactly once before returning to its starting position; SVPDP- Single Vehicle Pickup & Delivery Problem, In which each node is considered either as pick up node or delivery node and one to one, one to many, many to one or many to many relationship between pick up node set and delivery node set; SVPDPTW- Single Vehicle Pickup & Delivery Problem with Time Window, In which each node either pick up node or delivery node is associated with time window and Multi Vehicle Routing Problem-In this kind of situation or problem total of all services for goods demanded by all the nodes is greater than capacity of one vehicle.

Transit Routing Problem : He suggested good set of route considering existing transit demand, minimum transfer station and lowest travel time. He developed optimal scheduling model using Genetic Algorithm considering limited fleet size, policy headway , optimal stopping time for bus and compared derived results for various route models to the previous results derived by various researchers Mandl, Baaj and Mah, and Kidwai.

IV. INFERENCE

Referring to above research papers and studies following conclusions can be made in connection with Route Optimization of Bus Transit services for Urban areas.

- Various models of optimal Bus Route Transit Services have been developed by various researchers to maximise the operator's profit, to increase social Welfare, to help the transportation authorities, to reduce travel time and transit operators as a tool arriving the decision making process and to determine the best route network for particular study area considering various parameters such as Route Spacing, Route Length, Headway and Stop Spacing.
- The suggested optimal Route network developed on the basis of mathematical model or Genetic Algorithm or GIS or Software need to be rigoursly tested against operational criteria and practical consideration repeatedly and reviewed. Due to increasing population, increased Vehicular component and change in traffic condition to satisfy the demands of the population and increase the operator's profit.
- Proper scheduling, suitability of route and periodic reviewing of the system is required while designing as well as while implementing the transportation system at various stages.

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- Effective route optimization provide best services to the road user with highest possible degree of safety, Comfort and minimum time to satisfy transportation demand of society and reduction of transportation problems in a great extent.

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