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Developing An Integrated Planning System For Public Transportation At The Same Time

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ABSTRACT

This article is an attempt to design an Integrated Mass Rapid Transit System (MRTS) for the smart city project that is being developed in Western India. The article can also be read as an explanation of what an MRTS is. Integrated transportation is one of the reasons that makes smart transportation feasible. This aspect makes it possible to deliver a seamless transportation experience on both the intercity and regional levels. Smart transportation is one of the factors that makes smart transportation possible. For a smart city project to be successful at the city level for the purpose of transportation, it is required to provide adequate integration to various modes of mass rapid transit in order to meet the requirements of the project. Integration of information, physical, network of routes, fares, and other factors, among others, may be used to attain this goal. The method that was decided to use for this investigation was primary data research, and it was carried out in the form of a questionnaire survey. The people who took part in the survey and were given a questionnaire have responded to the questions that inquired about their thoughts on the ways in which the public transportation services in big cities may be enhanced by providing their comments. In addition, we asked the respondents to identify the traits and qualities that may encourage more people to start using public transit as their primary form of conveyance. In addition, the respondents were questioned about the concerns that, in their opinion, would be a barrier to the integration of various MRTS modalities. This was done in order to get their perspectives. In addition, the purpose of this research is to develop, with the assistance of multiple linear regression analysis, an equation that measures the utility of the respondents, as well as their likelihood of switching to public transportation based on certain factors that are outlined in the questionnaire. This equation will be developed in order to fulfil the purpose of developing an equation that measures the utility of the respondents, as well as an equation that measures their likelihood of switching to public transportation. When deciding whether or not to convert to public transportation, the two most important factors that need to be taken into consideration are the savings in travel time and the comfort rating of the vehicle. These are the most important aspects that have to be taken into consideration. In addition, an Integrated MRTS might be formed by combining metro rail with BRTS, metro rail with monorail, monorail with BRTS, and metro rail with Indian railways. Each of these combinations would result in a different type of rapid transit system. The result of each of these distinct permutations is a unique form of public transportation. Users of the transportation system should be provided with a single smart card that can be used to get access to all of the available modes of transportation. This would be a practical approach towards the goal of integrating the various forms of MRTS and would be a step in the right direction.

Keywords—Mass rapid transit systems, rapid transit system.

Introduction

Both the growth of India's population and the size of the country's urban centres are factors that contribute to the country's increasingly complicated transportation problems. Growing cities have a stronger inclination to have a rising number of travel functions that are becoming increasingly diversified and sophisticated, which can contribute to traffic congestion. Congestion, poor service levels, unequal modal splits, and pollution are just some of the problems that have surfaced as a direct result of the rapid urban growth that has taken place in the city of Delhi. This expansion has resulted in a wide array of issues that are connected to transportation. Because public transportation networks are unable to successfully fulfil the ever-increasing demand for travel, commuters are being pushed to move their means of transportation to private modes and paratransit. The term "paratransit" refers to a kind of public transportation that is intended to supplement larger public transit networks by offering individualised trips over shorter distances and without the use of set routes or schedules (Orski, 1975; Verma and Dhingra, 2005). As a result of this, it is of the utmost importance to develop networks of public transportation and to adopt solutions that are favourable to the environment in order to address the challenges posed by transportation problems.

The population of Delhi was counted in 2011 and the results indicated that around 97.5 percent of the city's inhabitants live in urban areas, while just 2.5 percent of the population lives in rural areas. As a result, Delhi is now considered to be one of the most urbanised states in India (RGI, 2011). Despite a consistent and rapid increase in demand over the course of the previous few decades, the public transportation systems in the city of Delhi have been unable to keep up with the growth in demand. Bus service levels in particular have declined, and their relative productivity has dropped even more; as a direct consequence of this, passengers are being compelled to utilise individualised forms of transportation in addition to paratransit in order to complete their journeys.

It is generally accepted that integrated public transportation systems, which involve the merging of two or more modes of transportation, are a significant contributor to the improvement of public transportation operations. This notion is supported by the fact that integrated public transportation systems are becoming increasingly common. Such integrated systems are designed with the intention of providing travellers with seamless mobility alternatives and a wide variety of destination options by means of a public transport system that is user-friendly, easily accessible, secure, and affordable. Different modes of transport no longer have to be in direct competition with one another because to the implementation of these systems, which make it feasible for them to work together. As a result of this, the development of integrated transport has been viewed as a potential solution to the issue of an increase in the movement of personal vehicles on the roads of Delhi. This is because there has been a rise in the number of people using their own automobiles.

The act of determining future transport policies, goals, investments, and designs is referred to as "transport planning." This is done in order to get ready for the anticipated increase in demand to transport both people and goods to their respective locations in the future. It is said that a transportation system has integrated transport planning if it pursues an integrated strategy across a variety of topics, including I planning objectives; (ii) transport and land use; (iii) transport modes; and (iv) operation. This type of planning is necessary for a transportation system to function properly. When people talk about sustainable development, what they usually mean is development that satisfies the needs of the current generation without compromising the capacity of subsequent generations to meet their own needs. This is the common definition that people use when they talk about sustainable development.

The word "sustainable transport" is used to refer to the overall idea of transportation that is socially, ecologically, and climatically responsible, and the phrase "sustainable transport" is used to refer to this overarching notion. The objective of environmentally responsible transportation is to achieve a state of equilibrium in which the environmental, social, and economic pressures of the here and now are balanced against those of the future. The development of sustainable cities requires the implementation of transportation networks that are less harmful to the environment. A city that encourages integrated planning between land use and transportation in order to reduce the requirement for travel, to maximise the utility and value of spaces, and to enhance the effectiveness of energy use and the liveability of the city should be considered a city that has sustainable transport.

Development of an integrated transport-land

It is self-evident that the configuration of the city has an impact on the movement patterns of its inhabitants, and the distribution of activities is one of the key determinants of the population's movements across the city. The availability of transportation influences the decisions made regarding the location of the activities, which in turn moves “the economy of the city, its settlement structure, and, as a result, the social environment. On the other hand, the system of transportation plays an extremely important role in gaining access to these activities. Because of this, it is abundantly clear that land use and the transportation system are intricately intertwined with one another, and there is a growing need to integrate them in order to establish an environment that is more sustainable. This is one of the reasons why there is a growing need to integrate them”.

In single land use models, it is predicted that the future transportation system would not change, but in the more prevalent four-step transportation models, it is anticipated that the spatial pattern of land use will not change. Both of these predictions are expected to come true (Oryani and Harris, 1996). Since the year 1960, a number of different models have been developed in an effort to combine transportation planning with land use. These models have been produced as a direct result of this. According to Timmermans (2003), planning models of this sort may be broken down into three stages. These models are often referred to as Land Use–Transport Interaction (LUTI) models.

1. Aggregate spatial interaction-based models of the first generation, also known as first generation models; these models are based on aggregate data and on the concepts of gravity and entropy maximization;

2. The multinomial logit models of the second generation, which are based on the maximizing of the utility function;

3. The third generation is one that is based on microdata as well as activities and travel patterns.

Objective

1. This study was to evaluate an integrated public transport system.

2. Study on Development of a Simultaneous For Integrated Mass Transit Planning.

Methodology

The process for the design of the network is split into two stages throughout its whole. The first step is to design a collection of plausible routes, and the second is to identify the most effective combination of routes and the frequencies that go along with them for the network. The Genetic Algorithm is a metaheuristic technique to optimization that is used to determine the largest potential combination of numerous different courses to pursue. This is accomplished via the use of a computer programme called the Genetic Search Tree. The non-convex nature of the problem, in combination with the vastness of the search space, led to the selection of the Genetic Algorithm as the best possible solution to the issue.

Candidate Route Set Generation

At the beginning of the procedure, a candidate route set generating algorithm is utilised to give a pool of viable route alternatives. This is the first stage of the process. After that, these routes are used as input for the upcoming stage, during which a mix of routes is picked to serve as the ultimate solution for the network. After that, these routes are utilised as input for the subsequent stage. The process of creating routes is given information in the form of “terminal node pairs, an OD demand matrix, and a Network file (with node and links data). The routes are constructed between the terminal node pairs that are picked in accordance with the demand that is present between the nodes. Terminal node pairs are” almost always found in neighbourhoods that include a significant number of buildings that are used for either residential or commercial purposes. The Djikstra approach is applied in order to construct the routes that are both the most direct and the shortest possible between each pair of terminal nodes. “If the routes fulfil the criteria for maximum length, then they are added to the candidate pool of routes to” be evaluated further. If the routes do not meet the criteria for maximum length, then they are not included. Alternate routes are also developed in order to allow for the construction of a large number of distinct pathways. In order to do this, certain links from the path that is currently considered to be the shortest route are deleted. This clears the way for the discovery of new paths that cover lesser distances. It is expected that the standards for maximum route length, maximum route overlap, maximum permissible detour, and route duplication will be adhered to by the alternative routes. Because of this, routes that are highly comparable to one another are not eligible to be candidates for inclusion in the collection of candidate routes. Patnaik et al. 1998 offers an incredibly in-depth account of how the route set came to be developed.

At this point in the procedure, two different kinds of pathways will be discovered. As the name indicates, the network of lines that comprise the feeder system will always start or end at a large transport hub. This is because the major transport hub serves as the system's "feeder." These routes are planned to provide service to the need for non-feeder services while also catering to the needs of customers who require transfer and feeder services. The travel times on these alternative routes are significantly reduced. As a direct consequence of the finding of these paths, it is strongly recommended that “an integrated network design be established. These routes are incorporated into the candidate route set, which is gradually transitioning into the role of the route pool”.

Route Set Optimisation

This phase searches through the pool of potential routes in search of the best feasible combination of roads to travel on (CRS). The task of determining the optimal path is posed as an optimization challenge, with the goal being to identify a path that minimises the total expenses incurred by users and operators while adhering to certain parameters, such as minimum and maximum frequency and load factor. The task is posed as an optimization challenge because the goal is to identify a path that minimises the total expenses incurred by users and operators. The entire amount of time spent travelling is referred to as the user cost, and it is the first term in this objective function. Equation 1 includes this term in its representations. (taking into account the time spent travelling in the car, waiting, and transferring) This is obtained by computing the sum of the product of demand (d) and total travel time (TT) over all of the routes that were chosen from the network. The TT refers to the total amount of time spent travelling. The second component, which is used to show the cost of operating the bus, is determined by performing the calculation of multiplying the total amount of time that the bus is on the road during a single trip (Tk) by the total number of times that the bus is on the road (k). The target function that was utilised in the process of determining the user and operator expenditures is shown as a representation in Equation 2, which can be found below.

$$Min\ Z = C_1 \left[\sum_{i,j=1}^{n} d_{ij}\, TT_{ij} \right] + C_2 \left[\sum_{k=R} \lambda_k T_k \right] \qquad 1$$

$$Z = ((Tt + (D_{un} * Des_{Dur}) + bus\_pty)U_c + bus\_km * O_c)/T_{dem} \qquad 2$$

The objective function, represented by Z, the total travel time, denoted by Tt, and the unsatisfied demand, denoted by Dun are the variables that are being considered. The required amount of time for the trip, which is represented by DesDur, as well as the "bus penalty and the total number of kilometres that each bus will have to travel are indicated by Bus pty and bus km, respectively. The operator part of the objective function" only takes into consideration the total number of kilometres travelled by buses since the distance traversed by the newly constructed public transportation lines is a fixed and unalterable variable. Since this is a number that is always the same, it does not have any effect on the way the objective function varies and, as a result, it may be ignored when working out the objective function. The variables that represent comparative user cost and operator cost are referred to as Uc and Oc, respectively, while the variable that represents total demand is referred to as Tdem.

Trip assignment is carried out for the network in order to ascertain the user expenses and the operator charges at their respective monetary values. There are several routes plotted out for each OD pair, and trip assignments are decided based on frequency sharing criteria for a limited portion of the available routes. In contrast to the method that was used for the creation of the transit routes, an integrated approach was used for the trip assignment in this study. This is one of the main differences between the two aspects of the research. "In the conventional technique of trip assignment for selecting transit routes, direct routes are given precedence over transfer routes. Transfer paths are also known as indirect routes. This is in line with the behaviour of the user, who would like not make any transfers at any time for the entirety of their journey. When it comes to trip assignment, a route that involves one transfer is only recognised when there is no direct route, and a route that involves two transfers" is only recognised when there is neither a direct route nor a route that involves just one transfer. In a scenario in which there is only one mode of transportation, this strategy is appropriate for the creation of routes; however, it is insufficient when a mass rapid transit system is added to the network. This inquiry makes use of a unique technique that is firmly rooted in the real world and is ideally suited for use with networks that consist of public transportation systems.

For each OD pair, this approach counts the number of direct pathways, the number of pathways with one transfer, and the number of pathways with two transfers. These thoroughfares have the potential to become a component of one or more systems of public transit. This is significant because, in a network that contains a mass transit system, a route that requires two transfers and uses both the "metro and buses may be significantly faster than a route that uses only buses as the mode of transit and does not require any transfers at all. This is one of the reasons why this is the case. Even though using this method of simultaneously identifying all direct, one transfer, and two transfer routes increases the amount of time" required for computation by a large factor, it is essential for all of these routes to be identified in order to select the route that is most appropriate for assignment. In other words, the most appropriate route is the one that has the fewest number of transfers. These routes are ranked based on the amount of time it takes to travel from one location to another location, and the routes whose “travel time is at most times” the travel time of the route that is considered to be the fastest route are chosen for demand assignment on the routes. Applying frequency share rules allows for the demand to be segmented in accordance with the frequency proportions for the routes that are to be assigned, which in turn allows for the trip assignment to be decided upon. The pathways that have more frequent service receive a greater volume of traffic. This is in accordance with the assumption that customers will be likely to pick a route where the first bus comes if the other routes are virtually equally quick in terms of their travel time. The total trip time includes the time spent in the vehicle, the time spent waiting at the beginning of the journey and during the transfer, as well as any transfer fines. The penalty is proportional to the length of time necessary to switch modes as well as the pain experienced by the passenger during the process of switching modes.

The genetic algorithm that Holland developed in 1992 is applied in order to minimise this function and locate the optimal path that should be taken as the solution. At the beginning of the CRS process, a random selection is used to establish a population of frequencies that are associated with each route. Any route with a frequency that does not comply with the minimum or maximum frequency requirement will not be included in the list of solution options. The trip assignment for this particular solution route set has been completed. Additionally depicted as prospective routes are the mass transit lines (MTL), but with predetermined frequency and individually distinguishable qualities (higher link speed) “(higher link speed). The velocity and frequency of the MTL are determined using the standard data that is readily available. The mass transit lines are never removed from the solution route set; nevertheless, they are not considered while the evolutionary algorithm is determining which operators to use. This is done to avoid the MTL from being removed in later generations. Reproduction, genetic crossover, and mutation are the three operators that are utilised in the process of generating the next generation. Because of the enormous size of the candidate route set, this is an extremely computationally expensive programme”. As a result, the number of generations is being used as the stopping criterion because it might take a significant amount of time and resources to converge on an optimal solution.

Study Area & Data Preparation

The metropolitan region of Mumbai in India was selected as the research location because of its enormous population and diverse urban landscape. This location, which is located on the west coast of the region, has very high population and has been one of the regions in the city of Mumbai with the highest population growth. At this time, the region is being served by a huge network of suburban train lines as well as various networks of bus lines. With an average of 7.6 million passengers each day, the suburban trains have been the region's most important form of transportation for decades. It has been suggested that the region implement a metro system in order to alleviate the traffic and congestion issues. At the moment, only one of this metro's routes is actually running, while the others are either in the building phase or the tendering phase. Other forms of transportation in the city include private automobiles, taxis, two-wheeled vehicles, walking, and intermediate levels of public transportation (IPT).

The CTS report is where we got the information for the network, which includes the information on the nodes and links, as well as the statistics on the OD demand (LEA Associates, 2008). This study served as the basis for the development of a CUBE model, from which the data was subsequently retrieved. The existing suburban rail line as well as the projected metro line have both been regarded to be fixed lines for the purposes of this analysis. This means that their routes and frequencies have already been determined. In addition, the data for the route nodes and the frequencies have been taken from the report. The establishment of the route in CRGA necessitates the use of transfer OD demand data, which is necessary for the feeder route set (FRS). This OD demand information is gleaned from the trip assignment outcomes provided by the CUBE programme. After the assignment of public transit has been completed in CUBE, the pathways that need to be enumerated and assessed for each OD pair are then retrieved from CUBE. In addition, these routes provide transfer data, such as the transfer node and the mode that was selected. With the use of these numbers, an "OD matrix representing the transfer to or from the metro is developed. After then, this OD is incorporated as a component in the process of creating the feeder routes".

RESULTS AND DISCUSSIONS

Table 1 provides an illustration of the input parameters that were utilised for the research project "for both the candidate route set development and the route set optimization". According to the statistics from 2031, the network and demand details are as follows: A proposed route set that included both feeder routes and non-feeder routes was developed for consideration. In the first phase of the suggested technique, a collection of candidate routes consisting of 5271 different routes was developed, and a total of "7049 node pairs were selected to act as terminal node pairs". 596 of the 5271 routes were considered to be feeder routes. After that, the candidate pool is put to use for the next stage of the process, which involves carrying out route set optimization.

It takes a 16-core Intel Xeon processor 52 hours to run through 1000 generations while performing the route set optimization, which is an extremely computationally intensive process. A population size of 16 was decided upon since it was equivalent to the number of processing cores that were made accessible, which allowed for the achievement of speedier results. The progression of the value of the goal function across the generations is shown in Fig. As can be seen, the value of the goal function is following a downward trend, which indicates that the genetic algorithm is moving closer and closer to the global minimum. The kink in the middle of the graph may be seen as a representation of a genetic algorithm that is attempting to break out of a local minimum by searching in an area that is impossible to find. "It also indicates that the weights for user and operator costs need to be set in such a way that there is a balance between the total values of operator and user cost, preventing either of them from becoming dominant in the objective function. This can be done by setting the weights for user and operator costs in such a way that there is a balance between the total values of operator As seen in Figure 1. The overall journey time of the user and the bus kilometers follow a trend toward reducing, which reiteratively demonstrates the efficacy of the algorithm in delivering an efficient network design for the region".

"Table 1 Input Parameters for Route Set Optimization Program"

Parameter	Value	Parameter	Value
Population Size	16	Bus Link speed (m/min)	250
Generations	1000	Metro Link speed (m/min)	450
Crossover Probability	.5	Suburban Link speed (m/min)	750
Mutation Probability	.0006	Bus Capacity (passengers)	80
No. of metro lines	22	Metro Capacity (passengers)	1800
No. of suburban lines	55	Suburban Capacity (passengers)	4500
Weight for user cost	.155	Weight for operator cost	4.49
Min freq for buses (in min)	60	One transfer penalty (min)	5
Max freq for buses (in min)	12	Two transfer penalty (min)	15
Max no. of 0T routes allowed	50	Size of FRS (no. of routes)	596
Max no. of 1T routes allowed	30	Size of CRS (no. of routes)	4675
Max no. of 2T routes allowed	15	Size of CRG (no. of routes)	5271
Total OD pairs for assignment	20,866	Total Demand for Assignment	5,31,207

In Table 2, the network parameters are laid out for the optimal solution that was reached after 1000 generations of testing. The proposed technique yielded an average time spent in the vehicle of 94.6 minutes for each passenger and per journey for the scenario that was being forecasted. According to CUBE Voyager, the average IVTT that may be attained "for the current bus, metro, suburban, and Intermediate Public Transport (IPT) lines in the city for the" year 2031 is 76.2 minutes per passenger each trip. This is based on the same demand matrix. When compared to the figure produced using the recommended technique, this is an 18 percent decrease. There are several explanations for why the values are so dissimilar to one another. The inclusion of IPT routes in the CUBE Voyager model is the key justification for this decision. "These IPT routes have a shorter average travel time during peak hours, and as a result, they have a tendency to have a lower average IVTT. In remote places with little demand, IPT proves to be a more cost-effective mode of transportation than buses", both for those who utilise the service and those who operate it. As for the network that will be used in the suggested technique, the IPT network will also be attempting to be supplied by buses; however, the expenses associated with their operators will be far greater. It is feasible for the bus operating agencies in the MMR to incur losses even while they are delivering services to the general people because these companies are controlled by the government. At the moment, the bus companies that operate in MMR are suffering enormous losses because to the extremely expensive expenses of operation. Because the user costs and the operator costs are both part of the goal function for the suggested technique, the methodology looks for a middle ground between the two. This fair solution guarantees that neither the operator nor the user will incur any damages as a result of their participation. The existing bus frequencies in the system are comparable to the minimum frequency (60 minutes) and maximum frequency (12 minutes) that were calculated using the suggested methods in Table. The fact that only 70 percent of the total demand was met "can be attributed to the impracticality of operating buses in areas where there is only a marginal need for them. In a city, such demand is typically met by IPT because it is significantly more rapid and demand responsive than buses, which operate according to predetermined schedules".

Table 2 Network Characteristics for the Solution Route Set

Parameters	Values
No. Of Bus Routes	1109
Zero Transfer Demand (% of total)	5
One Transfer Demand (% of total)	29
Two Transfer Demand (% of total)	36
Waiting Time (min/pax)	20.6
In vehicle travel time (min/pax)	94.6
Total travel time (min/pax)	135.93
Bus kms	2,29,918
Fleet size required	4,933
Avg route length (km)	18.73
Avg_route frequency (min)	20
Number of routes chosen from FRS	134
Number of routes chosen from CRS	975

Conclusion

"This study primary objective has been to develop an integrated land use and transport model that could provide local authorities with a useful decision-making tool to allow for urban sustainability, reducing the use of private transport by encouraging the use of the mass transit system that is currently available". This study was carried out in order to accomplish this primary objective. Because of this, much of the focus has been placed on a method that involves relocating activity volumes in order to reduce the amount of unused capacity that is present in the public transportation system. In the macro-simulation programme known as Visum, simulation models of all possible variants, including the existing transportation system seen in version V0, have been developed and run through the software. The use of Visum resulted in the development of a set of parameters and measurements that were utilised in the computation of all previously established criteria. These parameters and measures have been employed in the following: Because of the outcome of a computational experiment that was carried out using the Electre III/IV method, it was possible to calculate the final ranking of variations. the migration, as well as appropriate urban policy. At this point in the research, no behavioural models have been added; however, future advances may include “a modal shift model to validate the efficient use of public transportation for the trip demand involved in the move”.

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