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Global Efforts Towards Integrated Public Transportation Planning : A Brief Review

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***Abstract* - Public Transportation scenario in many cities across India and worldwide shows lack of integration. Several existing and proposed transportation modes have been considered in an isolated manner and have been developed independently without giving any due consideration to changing land-use dynamics. Due to this, public transportation has become increasingly less competitive and private vehicles have become more popular. In absence of integrated approach, these modes, instead of complementing are competing with each other and resulting into inefficient and poor performance of the transportation modes. This paper attempts to review various aspects of integration of a Public Transportation System. Various planning models prepared and adopted worldwide for implementing the particular aspects of integration have also been studied. A glimpse of efforts towards Public Transportation Planning in cities worldwide is reviewed to arrive at conclusions highlighting importance of Integrated Public Transportation Planning.**

Keywords - Integrated Public Transportation, Mass Transportation, Multimodal Transportation.

INTRODUCTION

Mobility demands are increasing at an exponential rate due to rapid population growth coupled with urbanization phenomena and rising population levels. The resulting exponential increase in urban mobility demand is met broadly by either personal or public modes of transportation. Public transportation is an effective mode available for mobilizing people as it is less costly than private transport. In addition, it can cater for simultaneous movement of a large number of people at the same time. Public transportation systems are modes of passenger transportation that are open for public use. Public Transit (also called as Public Transportation, Urban Transit and Mass Transit) includes various modes using shared vehicles to provide mobility to the public. The most popular Public Transportation Systems in use can be classified as follows.

1. Road based Transportation - Bus as a mode of Public Transportation:

a) Conventional Bus Transport consisting of mini busses, medium and large size commuter busses with fixed routes and schedules, moving people within a city.

b) Bus Rapid Transit with large size commuter busses having separate right of way for moving people across the city.

c) Shared Taxi as feeders to the Primary Public Transportation System and cross city travel to a certain extent.

2. Rail Based Transportation:

a) Heavy Rail having high capacity and speed with dedicated right of way for moving people through larger distances.

b) Light Rail Transit (LRT) having medium capacity and speed trains, operating mainly on dedicated right of way for moving people between residential areas and commercial and work centers.

c) Metro Rail having medium capacity but higher frequency as compared to Heavy and Light Rail having dedicated right of way.

3. Road Rail based Public Transportation:

a) Streetcars (also called trams or trolleys) are relatively small, lower speed trains, operating primarily on urban streets, with frequent stops which provide service along major urban corridors.

4. Water based Public Transportation:

a) Ferry services which are available in areas with water bodies for moving people.

Public Transportation is synonymous to Mass Transportation. It has been described in the Encyclopedia Britannica as “mass transit, also called mass transportation, or public transportation. It involves the movement of people within urban areas using group travel technologies, such as, buses and trains. The essential feature of mass transportation is that many people are carried in the same vehicle (e.g. buses) or collection of attached vehicles (trains). This makes it possible to move people in the same travel corridor with greater efficiency, which can lead to lower costs to carry each person; or because the costs are shared by many people; the opportunity to spend more money to provide better service, or both.

Evolution of Public (Mass) transportation:

The Mass transportation has evolved with the evolution of technology, from walking, to riding animals, to riding in groups on vehicles pulled by animals, and then to cable cars, larger-capacity steam-powered trains, electric trains, and motor buses powered by internal-combustion engines. The

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Public transportation was available in form of horse driven omnibus, horse carts etc. in the eighteenth century. Cable cars, trolleys, trams and double-decker's including the London Underground train and the L train in Chicago were seen in the nineteenth century. The double decker bus and motor bus were developments of the twentieth century. The steam, diesel, electricity powered trains with forms such as; Metro, mono and Suburban rail system being in vogue at present. The first bus rapid transit system (BRT) in the world was started in 1974 in Curitiba in Brazil [1]. The London Underground is the world's first metro system with electric trains which began operating in 1890 [2]. It is seen that throughout the period of evolution the characteristics of mass transportation such as speed, vehicle carrying capacity, and distance of travel, safety and comfort has improved to a great extent.

Concept of Integration

Integration is defined as the way parts of the public transport network are embedded in the total mobility chain. Transport Integration means that whatever modes or types of transport (rail, road, water, and air) are involved, they all operate as one 'seamless' entity - for the benefit of the fare paying customer [3]. Preston and others [4] define urban transport integration as the organizational process through which the planning and delivery of elements of the transport system are brought together, across modes, sectors, operators and institutions, with the aim of increasing economic and social benefits. The integrative aspect of this approach towards Public Transportation lies in the fact that, within this geographical area, the approach selects an optimal mix of different public transport systems services or modes; such as urban, regional and interregional bus; tram; metro; regional, interregional, intercity and international train. The concept of effectiveness of integration is defined by Syzmon [5] and others as a percentage share of travels carried out by both private and public transportation means in a total number of metropolitan travels within an urban area.

Challenges to Integration of Public Transportation:

The public transportation network is spread over many jurisdictional boundaries which do not necessarily lay any ground for integration, for example the local bodies do not have jurisdiction over rail services. This bars physical, informational and fare integration. A further barrier to integration is the fragmented ownership of public transport with fragmented physical network ownership stretching across several statutory bodies, duplication of procedures, failures in communication and the lack of clear and resourced responsibilities. Another important challenge is absence of transportation plans that interact beyond jurisdictional boundaries; such that the entire public transportation system acts as a seamless network. The topological structures, spatial connectivity, distances and prescheduled time tables of the individual public transport modes pose a hurdle while integrating one mode with the like characteristics of other modes of Public Transportation [6].

Integration of Public Transportation

The integration of all modes of public transport is necessary so as to facilitate greater mode choice, accessibility and reduction in waiting times and travel time. Effective integration is possible through a threefold process. The foremost is institutional integration with coordinated planning. Secondly there has to be physical integration; ensuring spatial connectivity of network through interchanges and hubs, thus providing a seamless travel experience. Lastly there has to be integrated operations achieved through information and fare integration.

A Public Transport System is made of three kinds of integration [7]:

• Infrastructural integration, which consists in dedicated transport infrastructures, as park-and-ride facilities, interchange stations, bus Priority lanes:

• Modal integration, which consists in the possibility to use different kind of Public transport modes (bus, rail) within coordinated timetables;

• Fare integration, which enables passengers to use different transport modes and services with the same ticket

System integration has three levels viz., institutional, physical, and operational [8] and others have further elaborated that Institutional integration involves joint planning and operation of services under a unified organizational framework. Physical integration involves connectivity between modes by provision of feeder services and interchange facilities. Operational integration involves fare, ticketing and information integration among modes.

Institutional Integration

Institutional integration consists of formation of a body having a regulatory institutional framework which coordinates between various transportation modes and their providers in such a manner that the entire Public transportation system should be perceived by the user as a single seamless means of transport. Institutional integration incorporates taking care of financial, operational and developmental aspects covering various agencies involved in context to the PT network. Several Cities in the world have Institutional integration as regards Public transportation which has been enumerated in Table no 1.

Physical Integration

Physical integration of mass transportation incorporates two important aspects such as availability of interconnecting transportation infrastructure network and public transport modes running on the network. The integration of the transportation infrastructure network is the first step towards Physical integration. The next step being integration of various modes running on the network. The Integrated Public transportation network from the planner's perspective is an interrelated network, nodes being the basic components of the network between which lines are interconnected with intermodal interchanges emerging through the formerly separated transportation system. Intermodal transport can constitute complex trip chains, creating high demands on interfaces and operational integration of the transportation system. [9]

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The integration of public transportation has been attempted in various cities across the globe by application of transportation models which have been developed for the individual cities. An integrated multimodal transport model (MTM) has been developed by BKK Centre for Budapest Transportation network. It provides for integration of walking and cycling along with local public transport and railways. The network design consists of number of nodes, links, connectors, stop points and line routes based on travel time [10].

Public Transportation system can be looked upon as a hierarchical network of Public transportation modes. The intercity rail would form the principal stage with the suburban rail, metro rail and bus rapid systems forming the middle stage and mono rail, tramways, regular busses, mini busses forming the lower stage of the hierarchy of the Public Transportation system. The hierarchical system of physical integration aims at grouping number of travelers and feeding them to higher ranking Public Transportation modes. Such a hierarchical public transit network has been proposed by Jian and others [11]. It consists of mass routes e.g. Rail transit, feeder routes operating along arterial and sub arterial routes and supporting local routes. A model for optimal trip distance of each route hierarchy type is proposed based on passenger features in the public transit system. The model uses a method of macroscopic calculation on hierarchy planning, which is based on turnover balance between supply and demand of passengers for hierarchy configuration of the public transit network. Such a network ought to be improvised according to rising demands for Public Transportation. This is attempted in the model developed by Zhu and others [12], which defines new links based on demand using genetic algorithm. It is based on the principle that the potential demand of a link is inversely proportional to the average distance of passengers to be attracted to that link.

Further metaheuristic optimization algorithms have been used by [13] to prepare a multimodal transit model to suggest a strategy for designing transit networks that gives multimodal public transportation options at each stop so that modal split can be facilitated. The model helps in designing multimodal feeder services, coordinating with an integrated transit system and optimization of the multimodal transit network plans. The parameters used for optimization were travel cost, passenger trip demand, fleet size, route length, vehicle length and headway.

The modes of transportation that interact in an integrated mass transportation system are the motorised bus, bus rapid transit (BRT), metro, mono or suburban rail and waterway ferries. There is also some interaction with inter-regional transport such as state transport busses, trains and airways. The physical integration between various modes is achieved through interchange stations and multimodal hubs interconnecting the network and the various modes. The regular bus is the most common mode of public transportation in cities. They not only serve as a primary mode of Public Transport but are also used as feeder services to other modes such as a BRT, suburban rail, metro or LRT.

Operational Integration

As emphasized by Pawan Kumar [8] the provision of feeder service to various modes of transportation is an important aspect of integration. The integration of feeder bus system to other modes requires design of trip routes, schedules, headways, travel speeds, frequencies and their coordination for the operational integration of public transport modes. This is done by using optimisation techniques on the basis of demand and supply figures of potential riders.

The routing and scheduling problem was assessed by Lu and Wang [14]. They used a compatibility-based algorithm which can allocate seed passengers for initialising and routing routes and scheduling the feeder service. It also can propose a Demand Responsive Connector to provide feeder service for commuters from and to the transit hub.

The next stage in Public Transportation system hierarchy involves integrating busses with the Bus Rapid Transit system. A nonlinear programming model with single objective and multiple variables using Genetic algorithm for coordinated operation BRT and its feeder bus has been proposed by Wu and others [15] . It aims at reducing the costs of passengers such as waiting costs, transfer costs, and in-vehicle costs. The model also suggests optimised headways of the BRT and bus networks as an effort to Public transportation Integration.

Integration of Feeder busses to Railway stations is an important aspect in the Public Transportation network. Deng and others [16] has proposed a model for an integrated public transport system of a feeder-bus network and railway. The model generates optimised feeder bus routes by generating connection relations to bus stops. Its unique feature is that it uses a demand distribution pattern wherein passenger demand is distributed between many railway stations and to many bus stops and that each such bus stop is served by one feeder-bus route only and it does not cross its feeder station. A model using Genetic algorithm has been developed by the Zhang and others [17] for the passengers who only take bus and the ones who take both the bus and the train in one trip. The results have shown that use of the long through-type bus line and several bus lines with independent operation, integrated with the railway stops respectively leads more passengers to choose combination of faster Public Transportation trip modes resulting in operational efficiency. A model for operational integration of suburban railway stations and public buses has been discussed by [18] . The model uses heuristic algorithm for integrating feeder bus public buses to suburban railway stations.

The focus of the integrated Public Transportation system is the potential rider. Passenger attributes that need to be considered are accessibility to the Public Transport system, location of stops, access distance, and wait time which is a factor of frequency, in-vehicle time which is a function of headway and vehicle speeds. The last but most important

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factor is the fare or travel cost. An analytical model has been suggested by Steven and [19] that optimizes the number and locations of bus stops, headway and fares. It considers discrete demand distribution over a transit route on a realistic street network. Demand decays of the access distance, wait time, in-vehicle time, and fare were also considered along with discrete feasible stop locations.

Fare Integration

Pawan Kumar and others [8] have mentioned that the techniques of operational integration include establishment of unified fare structure, ticketing and checking of boarded passengers and coordination of public information system. Fare integration has been achieved in many integrated transportation systems throughout the world. Helsinki, Finland, residents have the option of "Whim" app allowing passengers access to any mode of Public Transport. The city of Orleans in France, have a "Plan Book Ticket" app that combines all modes to let the commuter pick the best option. Similarly Portland-Vancouver Metropolitan have "Are Hop Fastpass" the first virtual transit card whereas Los Angeles region has "TAP" which links together 24 transit agencies [20].

Information integration

Information integration is an important aspect that allows a passenger to make travel decisions. With development and growth in communication technology, dissemination of information at the hands of the traveler has become easy through mobile applications and web based information systems. It was observed that users require well-integrated information systems to use a network efficiently. A model for information integration has been developed in form of free-to-use Android application in Auckland, New Zealand [21]; it helps commuters and tourist in decision making for multi-destination trip planning using Public transport. It can provide real-time Public transport route information for Public transport user multi-destination trip planning. Information systems are helping passengers to make travel decisions based on shortest trip time. Floyd-A∗ algorithm has been used by [6]the authors to determine the least-time itinerary from origin to destination in an urban scheduled public transportation network when given initial time to start the travel. An attempt has been made to provide probable travel time in order to choose a public transportation route in an urban scheduled Public Transport, so that he can select the walk route, boarding and transfer stops to reach their destination as quickly as possible.

TABLE I

SN	City	Institutional	Informa-tion App.	Fare	Physical Integration *Not integrated									Source www.
					Bus	BRT	Tram	Metro	LRT	EMU	Taxi	Cycle	Ferry	
1	London	Transport for London	IBUS	Oyester Card	X		X	X	X			X		tfl.gov.uk
2	New York	NY Metrpolitan T. A.	MTA bus time	Metro card	X	X		X		X	X*	X*		www1.nyc.gov, new.mta.info
3	Paris	Île-de-France Mobilités	Real Time Information	Navigo pass	X	X	X	X			X*	X*		rapt.fr
4	Hong Kong	Transport Department	Next Train Mobile	Octopus Card	X			X			X*			td.gov.hk
5	Singapore	Land Transport Authority	My Transport	EZ card	X		X	X	X		X	X		lta.gov.sg
6	Toronto	Toronto Transit Commission	Next Vehicle Arrival System	Presto Card	X		X	X			X*	X*		toronto.ca, ttc.ca
7	Moscow	Department of Transport	MosMetro Maas	Trioka card	X		X	X		X	X*	X*		transport.mos.ru
8	Vienna	Wiener Linien, Verkehrs- verb	Wien Mobil	Wien Karte,	X		X	X		X	X*	X*		hallo-austria.at, wien.gv.at
9	Sydney	State Transit Authority of NSW	TripView	Opal Card	X	X	X	X	X	X	X	X	X	Sydney.com/ transport, cityofsydney.nsw.gov.au
10	Beunos Aires	Metropolitan Transport Agency	BA Cómo Llego App	SUBE Travel Card	X	X	X	X		X	X*	X*	X*	turismo.buenos aires .gob.ar

Integration Efforts in Cities across the Globe

The Mckinsey Report [22] includes a study on important aspects of mobility that make transit systems work. This study was done by comparing Public transportation networks across 24 global cities. Selected cities mentioned in this report were studied and the efforts towards integration is shown in Table I

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CONCLUSION

The Integration of Public Transportation systems has been implemented in various cities worldwide. The strategy of adopting integrated multimodal transportation system is gaining importance. The Integration effort towards planning a Public transportation system should focus on Integration at Institutional, Physical and Operational levels. The Process of integration is a complex one involving multiple objectives. Physical integration involves establishing connectivity between different infrastructure networks and modes running on them. This has to be done through provision of multimodal interchanges. It further involves optimal design of routes, schedules, headways. Operational integration involves integration of fares, ticketing, and integrated passenger information systems. A coordinated effort towards integration should optimize travel time, travel costs, waiting times, in-vehicle time, ingress and egress times through interchanges. An integrated public transportation system should be perceived by the Passenger as a single unified entity and a journey should be seamless. These aspects have been considered from in the integrated transportation systems in cities which have been reviewed in this paper.

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