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Alleviating Transportation System Problems by Providing Public Transit Integration in High-Density Metropolitan Cities

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Abstract

Proper integrated public transport system is the need of the time which can enhance public mobility by providing state of the art transport services to daily commuters. In this paper, Lahore City is taken as a case study and an integrated public transport system for Lahore is proposed. The goal of an integrated public transport system for Lahore was to propose an optimized public transport network, which can cater the ever-increasing transport demand by providing coverage to the whole city through a mix of primary/mass transit, secondary/express, tertiary/feeder & suburban routes. The service would provide a high level of service by ensuring a speedy, frequent and easily accessible public transport to reduce car/ motorcycle dependency/ownership. The network aims at providing public transport access for residents in the study area at a maximum walking distance of 500 meters and offers a sustainable, comfortable, safe and secure public transportation system. Based on demand estimates taken from surveys, an integrated public transport network having 122 routes was proposed for the city.

Keywords: Public Transit; Integration; Transportation; Metropolitan; Urban Transport.

1. Introduction

Rapid global urbanization leads to a massive shift of population from rural to urban areas. Better health, education and employment opportunities are considered as the main driving force behind this phenomenon. This trend is extreme especially in developing countries where it is difficult to provide people with better health and education facilities due to limitation of resources. Therefore, people tend to move from rural to urban areas. By 2030 it is anticipated that the world's urban population will grow by 1.8 percent which almost double the global population growth rate [1]. Figure-1 shows the global trend of rural urban migration. This increasing trend of urban population leads to an increased number of commuters on roads, which loads the urban infrastructure and demands for immediate improvements.

Increased population will ultimately increase the vehicle ownership resulting in increasing delays on roads and intersections. In this regard, mass transit system is considered the most suitable solution for moving large masses of people from one place to another. Mass transit system includes an integrated network of Bus Rapid Transit and Rail Mass Transit making sure that public transport is accessible to all within minimum walking distances and minimal fares ensuring state of the art services to the commuters. Pakistan, a country having sixth largest population of the world is also facing the problem of rapid urbanization. The main urban centers of Pakistan include cities like Karachi, Lahore, Peshawar, Multan, Faisalabad and Rawalpindi. Due to lack of facilities people of urban areas migrate to these cities which are causing immense pressure on the urban infrastructure of these cities especially roads. The roads are getting congested day by day and the intersections are operating at a lower Level of Service (LOS) [2].

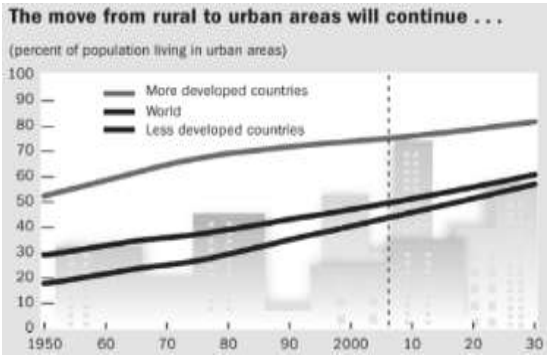

Figure 1: Global rural urban migration trend [1]

This study aims at minimizing the transit problems in high density metropolitan cities of Pakistan by providing an integrated public transportation system. The increased population of cities demands for a state of the art public

transportation system that can cope up with the rising number of commuters on roads. In this regard, an integrated system of public transport is the need of the time which can alleviate various transit problems of these high densities metropolitan cities. Public transit integration will cause a modal shift which will lead to a decreasing number vehicle in roads and ultimately improving the level of service of different intersections. Public transport integration provides speedy, convenient, and economical services to complete daily journeys [3]. This should include the integration of timetables, ticketing and provision of facilities such as parking spaces for park and ride; and special services for the disabled or elderly. The elderly and disabled population require favorable environments including access to public spaces which eases their mobility [4]. Public transport must be better and easily accessible, one of the means is by incorporating park & ride options which facilitate hop on and hop off via public transit after parking at the parking lots [5]. Ticketing systems must be compatible with all modes [6]. An integrated public transport system should provide a seamless travel to a passenger who can enjoy good services connection, reasonable waiting time at interchanges, comprehensive information and an integrated ticketing between different transport modes. Consequently, the system is essential to offer passengers an integrated travel using all public transport modes to suit their routing [2].

2. Study Area

For the purpose of study Lahore city, the second largest city with respect to area and population of Pakistan is chosen where public transport system integration will be proposed. Lahore was selected as the study area based on the availability of a mass transit corridor in the form of Green Line BRT and other proposed mass transit line alignments present in the Lahore Urban Transport Master Plan (LUTMP, 2011) [7]. Public Transport System Integration was proposed in conjunction to the available and proposed mass transit corridors for the city. Figure-2 shows the map of Lahore having all mass transit lines marked proposed in LUTMP [7].

3. Data Collection

For this study, data from several primary as well as secondary sources were collected. Primary data collection included different surveys whereas, secondary data was collected from various reports, past studies and master plans prepared for Lahore. The following surveys were conducted for the primary data collection:

1. Cordon Line Survey
2. Screen Line Survey
3. Roadside Interview Survey
4. Public Transport User Interview Survey

To collect the demographic information of the study area, household interview survey is conducted, but due to limitation of resources, demographic data for Lahore was taken from LUTMP-2011 with appropriate projections as proposed by JICA (Japan International Cooperation Agency) [8].

Figure 2: Map of Lahore and proposed mass transit corridor in LUTMP-2011 [7]

3.1 Cordon Line Survey

The boundary of Lahore was taken as the cordon line where a total of nine cordon (entry/exit) points were selected. Vehicles entering and exiting the city were counted. Figure-3 shows the map of Lahore having marked cordon line and cordon points.

Table 1: Cordon line survey results

Sr. No.	Name	PCU Volume Entry	PCU Volume Exit	Total (PCU)
1	Wagha Border	4,311	4,575	8,886
2	Ferozepur Road – Mustafabad	13,262	5,381	18,643
3	Kasur - Raiwind Road	5,475	4,467	9,942
4	Raiwind - Pattoki Road	3,908	2,707	6,615
5	Multan Road - Bhai Pheru	20,261	23,694	43,954
6	Babu Sabu Interchange	9,647	19,756	29,403
7	Ravi Toll Plaza	18,803	16,346	35,149
8	Jaranwala Road (Saggian Bridge)	29,956	24,447	54,432
9	Shahdara	51,580	62,832	114,412

Manual Classified Counting was conducted by trained surveyors counting vehicles as per vehicle classification such as bicycle, motorcycle, rickshaw/qingqi (a three wheeler motorcycle passenger carrier), car/jeep/pick up/taxi, wagons, minibuses, coasters, large busses, animal driven, tractor trolleys and 2/3/4 or more axle trucks.

Sixteen-hour manual (07 00 – 23 00 hrs) classified counting was conducted on account of getting peak hourly data, at the selected cordon points and Table-1 shows the cordon line survey results.

It was found that Shahdara and Jaranwala Road (Saggian Bridge) cordon points were the busiest with reference to traffic volumes.

Figure 3: Cordon points of Lahore

3.2 Screen Line Survey

The study area was divided into four parts using two screen lines as shown in Figure-4. Canal road and railway line passing through the city were considered as screen lines. Manual classified counting for a period of sixteen hours for the same vehicle classification used for cordon line survey was used. On Screen Line-1 i.e. Canal Road, manual classified counting was conducted at 21 different locations whereas, on Screen Line-2 i.e. Railway Line, manual classified counting was conducted at 22 different locations. Table-2 shows the names of the locations where manual classified counting was conducted on two selected screen lines.

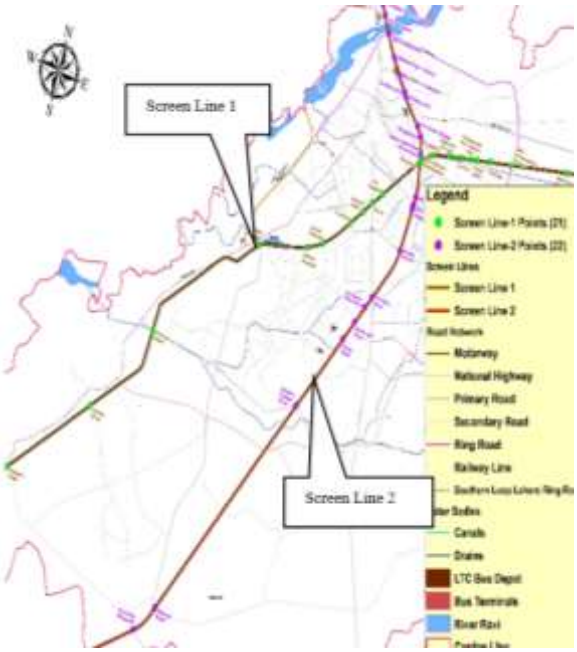

Figure 4: Screen lines of Lahore

Table 2: Screen line data

Screen Line 1: Canal Road		**Screen Line 2: Railway Line**	
Sr. No.	**Survey Location**	**Sr. No.**	**Survey Location**
1	G.T. Road-Barki Rd Link	1	Shahdara Town - Underpass
2	Jallo Park Access Road	2	Jahangir Tomb
3	Harbanspura Flyover	3	Lahore Ring Road
4	Taj Bagh	4	Badami Bagh - Flyover
5	Fateh Garh	5	Misri Shah - Underpass
6	Nawan Pull	6	Ek Moria Pull
7	Lal Pul	7	Do Moria Pull
8	Shalamar Flyover	8	Allama Iqbal Road
9	Chobacha	9	Dharampura
10	Dharumpura Intersection	10	Gari Shahu Bridge
11	Sundardas	11	Mughalpura
12	F.C. College	12	Mian Mir Bridge
13	Ferozepur Road	13	Jinnah Flyover
14	Muslim Town	14	Sherpao Bridge
15	Campus	15	Allaudin Road
16	Jinnah Hospital	16	Ferozepur Road
17	Doctor Hospital	17	Ferozepur - Peco Road
18	Thoker Niaz Baig	18	Depot Road
19	Sundar Road	19	Kasur Rd - Manga Rd
20	Defence Road	20	Defence - College Road
21	Raiwind Road	21	Raiwind Road
		22	Kacha Jail Road

Table-3 shows that more vehicles cross Canal Road Screen Line as compared to Railway Line Screen Line daily. Whereas, Figure-5 and 6 show the bar graph of traffic volumes crossing the selected screen lines daily. It can be clearly observed that the Canal Bank Screen Line serves more traffic as compared to Railway Screen line. This could be due to properly developed infrastructure along canal screen line.

Table 3: Screen line data

Sr. No.	**Screen Line**	**Traffic Volumes (PCU's)**
1.	Canal Bank Screen Line	1,592,221
2.	Railway Screen Line	1,454,964

3.3 Roadside Interview Survey

Road Side Interview Survey (RIS) was performed to collect information from private vehicle drivers and commuters of public transport related to their daily trip characteristics and problems. This survey helps in assessing the problems faced by private drivers and public transport commuters in specific relation to their trip completion. RIS was conducted on the cordon points during the cordon line survey. Figure-7, 8 and 9 shows the bar graphs pertaining to vehicle type, trip frequency and trip purpose collected during the RIS. It is observed that most of the trips were for Cars and the frequency was once daily. Work trips were found predominant during the study.

Since roadside interview survey was conducted at cordon points of the city, therefore, the quantity of cars and two axle trucks were dominant. However, significant number of motorcycles were also observed.

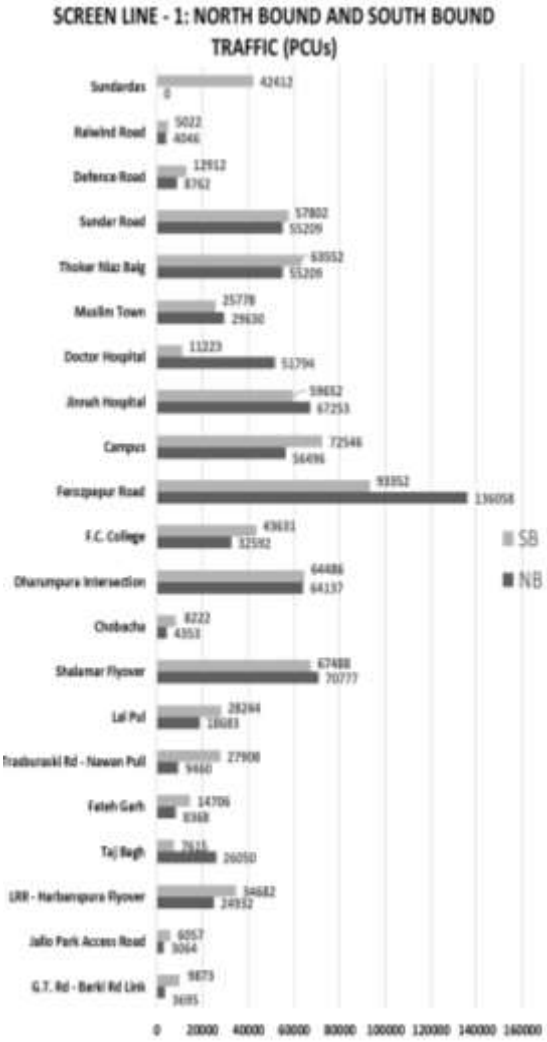

Figure 5: Screen line-1 traffic data

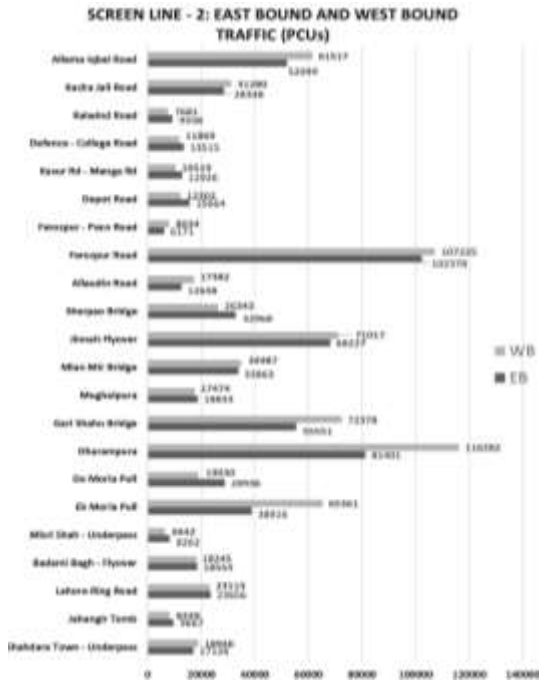

Figure 6: Screen line-2 traffic data

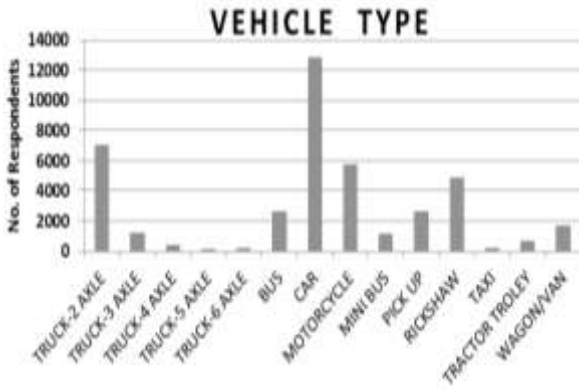

Figure 7: Vehicle type data collected using RIS

Figure-8 shows that most of the respondents of roadside interview survey had one or more daily trips in abundance which clarifies the abundant intercity movements within the city.

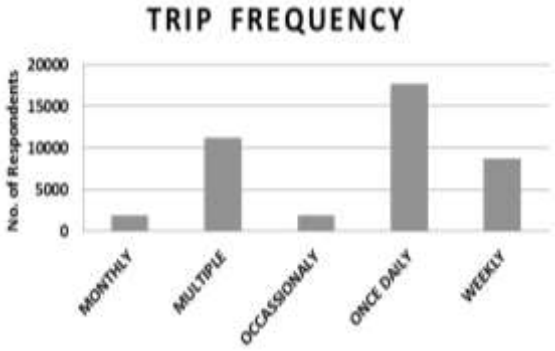

Figure 8: Trip frequency data collected using RIS

Figure-9 shows that most of the trips were either work based or home based trips.

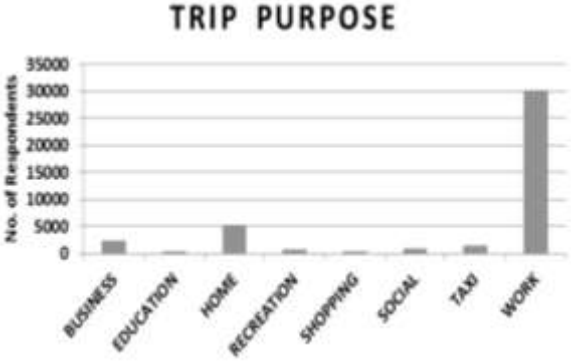

Figure 9: Trip purpose data collected using RIS

3.4 Public Transport User Interview Survey

Public Transport (P-T) User Interview Survey was conducted at five major bus terminals of Lahore as mentioned in Table-4.

Table 4: P-T user interview survey locations

Sr. No.	Name
1	General Bus Stand
2	Railway Station (LTC)
3	Railway Station (Daewoo)
4	Gajjumattah
5	R.A Bazar

Questions related to trip purpose, occupation of public transport users and ratings of public transport of Lahore relative to operating hours, route system, frequency, punctuality, safety, fare, affordability and access to bus stop.

Figure-10 shows that most of public transport users of Lahore belong to students, services and sales industry.

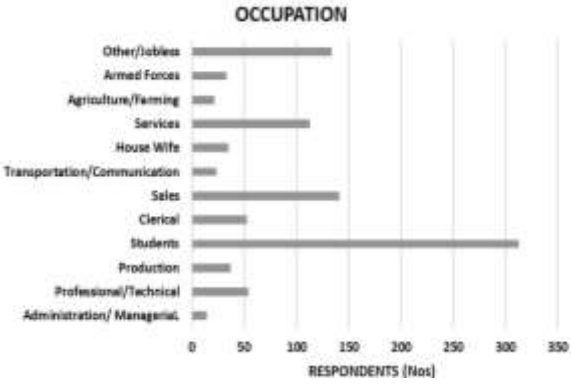

Figure 10: Occupation of public transport users

Figure-11 shows that most of the public transport user trips of Lahore are either home based or work based. Whereas, educational trips also hold immense importance.

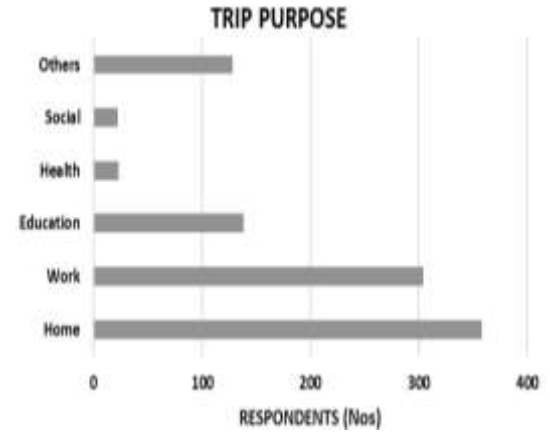

Figure 11: Trip purpose of public transport users

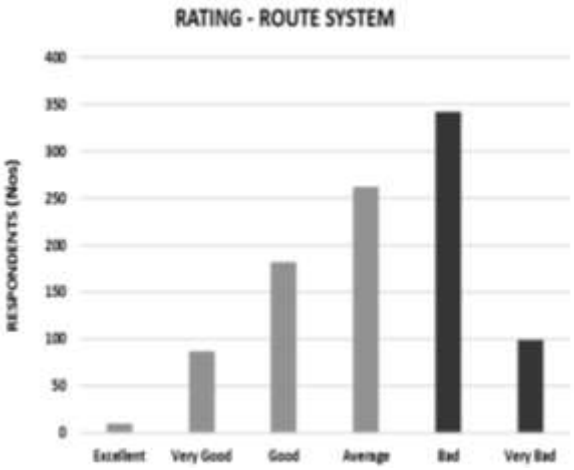

Figure 12: Ratings of public transport w.r.t. route system

Figure-12 shows that public transport users of Lahore rated the public transport route system of Lahore in bad to very bad category. Improvement in route system can convince people to shift to public transport.

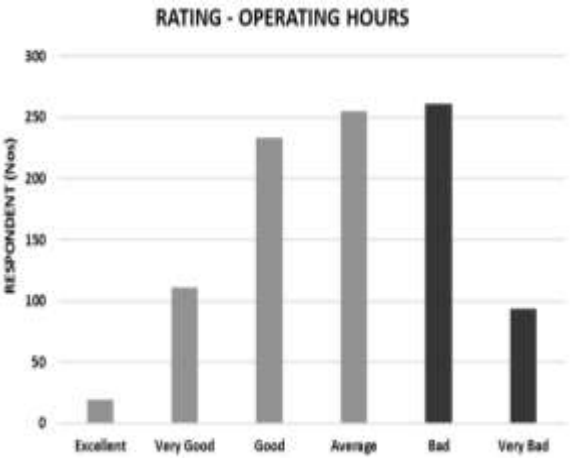

Figure 13: Ratings of public transport w.r.t. operating hours

Figure-13 shows that the operating hours of available public transport are also not satisfactory. Improvement in operating hours is required which can bring a drastic modal shift towards these modes, as a result of improved reliability.

Figure-14 shows the public transport ratings w.r.t. frequency. The results show that public transport users of Lahore are also not satisfied with the frequency of available public transport; therefore, improvement is required.

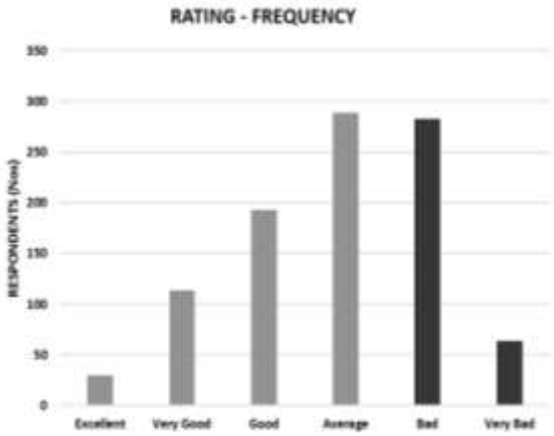

Figure 14: Ratings of public transport w.r.t. frequency

Figure-15 shows the public transport ratings w.r.t. punctuality of available public transport services. People rated the punctuality of available public transport in bad and very bad category; therefore, significant improvement is required.

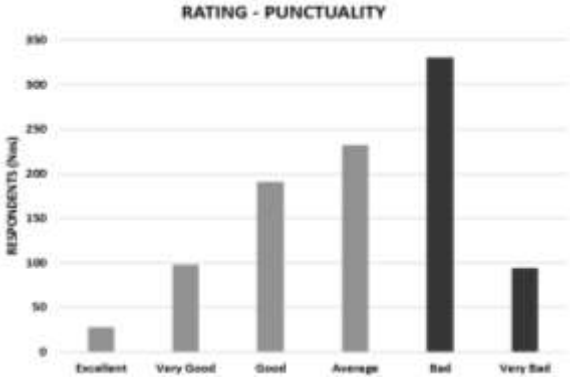

Figure 15: Ratings of public transport w.r.t. punctuality

Figure-16 shows the public transport ratings w.r.t. safety. Most of the respondents of this survey were of the view that public transport of Lahore is unsafe and threatening.

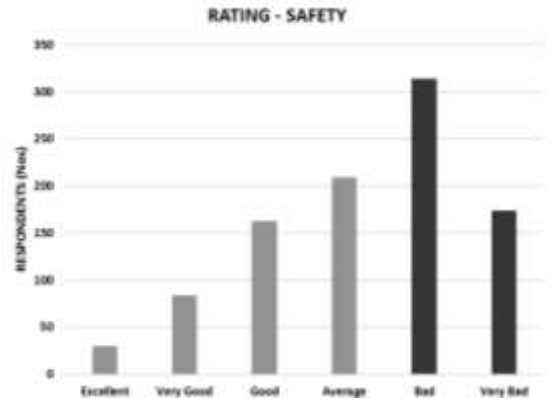

Figure 16: Ratings of public transport w.r.t. safety

Figure 17: Ratings of public transport w.r.t. fare

Figure-17 shows the public transport ratings w.r.t. fare being collected. Most of the respondents were of the view that the fare was not proper and high. People will shift if state of the art and cheap public transport services are provided.

Figure-18 shows the public transport ratings w.r.t. access to bus stop. The respondents were of the view that the bus stops are not properly spaced and the distance between them needs to be reduced.

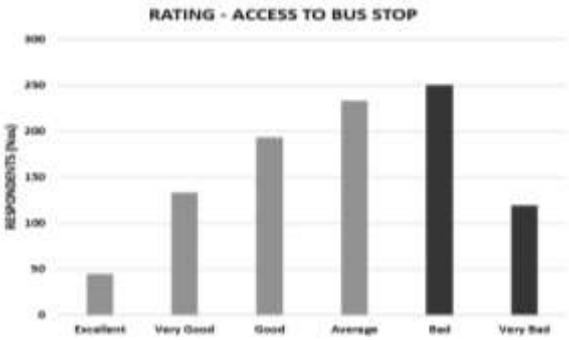

Figure 18: Ratings of public transport w.r.t. accessibility to bus stop

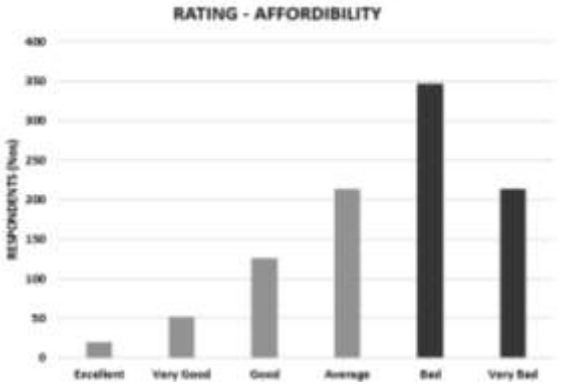

Figure 19: Ratings of public transport w.r.t. affordability

Figure-19 shows the public transport ratings w.r.t. affordability. Most of the respondents were of the view that the prevailing public transport system of Lahore is not affordable. To shift more people to public transport system, it should be affordable.

3.5 Socio-Economics and Demographics

As discussed before, due to large extent of the city and great number of households, it was not possible to collect complete demographic information for Lahore. Therefore, in this regard demographic data of LUTMP was used using proposed projections in Lahore Urban Transport Master Plan by JICA in 2011. Figure-20 shows the population pyramid of gender distribution of Lahore.

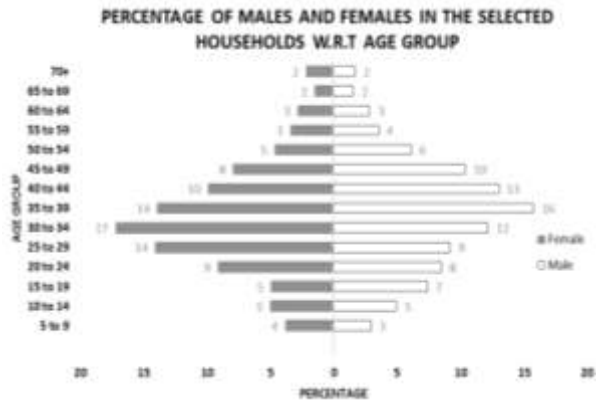

Figure 20: Population pyramid of Lahore

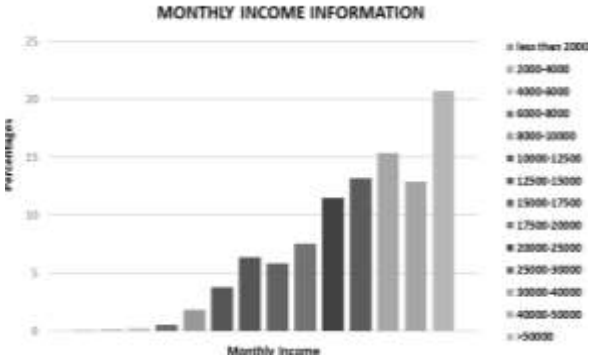

Figure 21: Monthly income information of Lahore

Figure-21 shows the household income of the residents of Lahore. To collect accurate information, three income groups were developed i.e. Low, Medium and High. Households having monthly income in the range of PKR 2000 to 20,000 were categorized as low income class, households having monthly income in the range of PKR 20,000 to 50,000 were categorized as medium income class whereas, households having monthly income greater than PKR 50,000 were categorized into high income class.

Table 5: Frequency of income groups from sample population

Income Range (PKR)	Number of Households
2000-20000	8,862
20000-50000	3,798
>50000	1,407

Table-5 shows the frequency of the income groups from sample population.

Figure-22 shows the education level of the people of Lahore. It was observed that most of the respondents were not well educated.

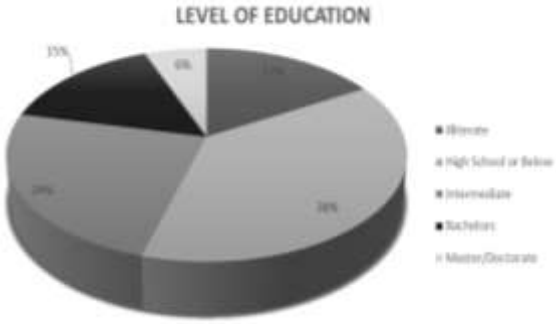

Figure 22: Literacy level in Lahore

Figure-23 shows the pie chart for the occupation of the people of Lahore. Figure-24 shows the house ownership information for the people of Lahore.

Figure 23: Occupation of respondents of Lahore

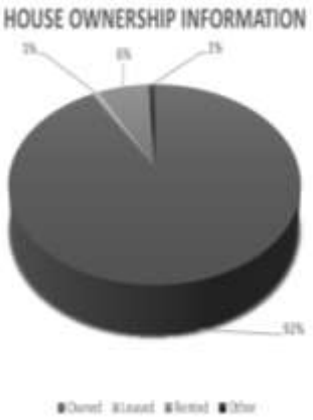

Figure 24: House ownership information

Figure-25 shows the most important information pertaining to public transport usage i.e. vehicle ownership. It was found that 62 percent of the respondents did not have any vehicle whereas, 38 percent of the population were owning their own vehicle. This clearly shows if we provide better public transport services then this number of 38 percent can be controlled and further minimized.

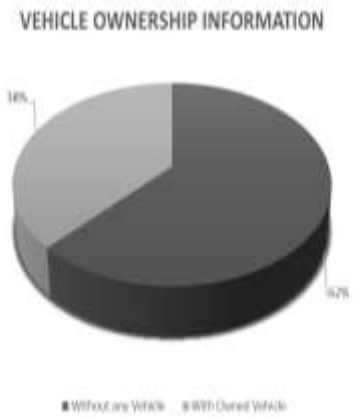

Figure 25: Vehicle ownership information

Figure-26 shows the information related to public transport users age group. It was observed that maximum people who use public transport were between 26-40 years of age.

Figure-27 shows the public transport usage trend of the population of Lahore.

Figure-28 shows the reasons of mode choice for Lahore w.r.t. various modes like animal cart, bicycle, motorcycle, car, rickshaw etc.

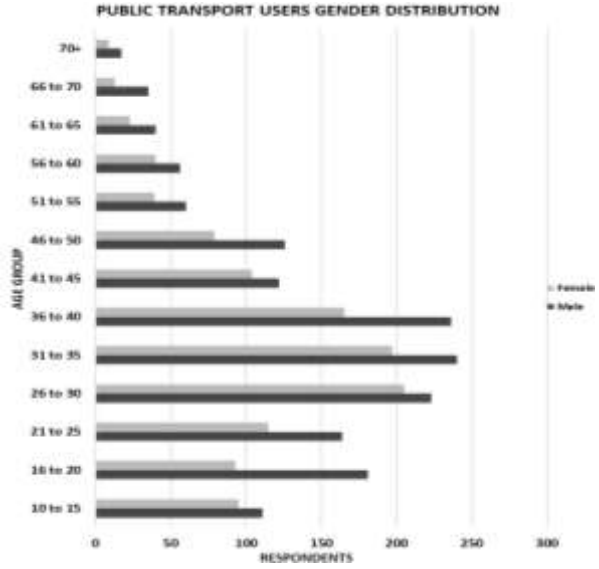

Figure 26: Vehicle ownership information

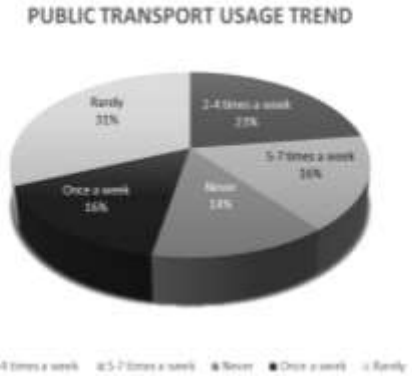

Figure 27: Public transport usage trend in Lahore

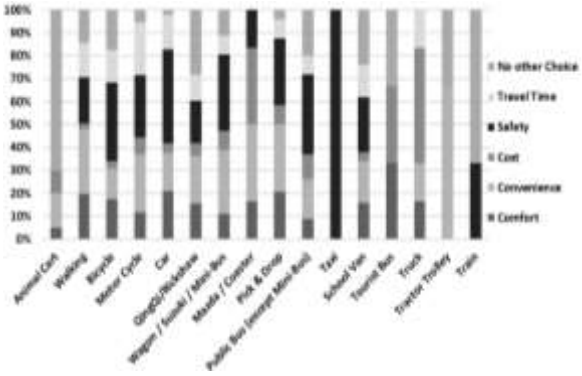

Figure 28: Public transport usage trend in Lahore

4. Public Transport Integration for Lahore

Integration of Public Transport means physical, operational, information and fare integration of public transport at all levels i.e. primary, secondary and tertiary routes [9, 10]. Integrated public transport has advantages for both the operators and users. Operating each route

independently reduces revenue collected per bus and increases cost of operation due to overlapping of routes. The integrated public transportation system reduces/eliminates route overlapping and thus offers an optimized route structure which in turn reduces operations costs and increase revenue per bus. Users benefit from free/discounted transfer thereby reducing out of pocket costs and increasing convenience for the travel as the passengers have an end to end solution within a single ticket. Figure-29 shows the basic parameters involved in public transport system integration.

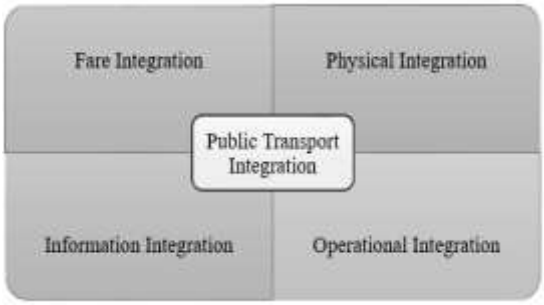

Figure 29: Public transport integration parameters

Public transport network integration plays a pivotal role in resolving the public transport problems of the city. At present, Lahore, has only one operational mass transit line i.e. Green Line which is a BRT system whereas, construction of Orange Line (Rail Transit System) has started with the aim of meeting the public transport demand. However, there is a lack of integration with the local public transport system of Lahore. An integrated public transport operation for Lahore is proposed and is meant to facilitate the commuters to not only use the already built or proposed mass transit lines of Lahore but also provide access to areas which are not serviced by mass transit.

The essence of an integrated public transport system is to make access and use of public transport easier for everyone [11, 12]. It should be able to link up and facilitate the development of an efficient and accessible network. Passengers will be satisfied only if suitable service frequency, high reliability, simplicity, and fare affordability are provided. These include better coordination between modes, provision of well-developed transfer facilities and better pedestrian access facilities. The provision of real-time information of public transport service and improved customer services can reduce barriers and enhance understanding. These criteria should result in better quality customer services for the public transport users.

The integrated public transport network for Lahore will be employed in the form of four categories mentioned below:

1. Primary Routes
2. Express Routes
3. Feeder Routes
4. Sub Urban Routes

Primary routes provide fast, comfortable and cost effective services. These routes are usually high quality bus rapid and light rail transit systems. Primary routes have dedicated right of way, typically aligned in the center of the road with state of the art stations and automated fare collection systems. The services on these routes will operate express routes with high frequency and high commercial speed (greater than 25 km/h). In case of Lahore, Green Line i.e. BRT and future Orange Train are considered as primary routes.

Express routes operate on major roads and connect major terminals. Public transport services operating on these routes are intended to provide faster service than normal bus services. Public transport operates on express routes runs faster by making less frequent stops than normal bus service. The commercial speed on such routes is expected to be more than 22 km/h. In case of Lahore, express routes are proposed on all major roads of Lahore depending on the cordon and screen line data collected so that load on major road network of Lahore may lessen.

Feeder routes operate on secondary and tertiary roads. Feeder routes are designed to pick up passengers from low density areas and take them to a transfer point of primary or express routes where they continue onward journey on bus rapid or light rail transit system. Route lengths of feeder system are normally less the 10 km. In case of Lahore, commuters from far flung areas of Lahore where previously no public transport access was there will be brought into the network using these feeder routes. Due to less population in those areas, it is anticipated that less passengers will board the feeder bus therefore, it is recommended that mini busses should be used as feeder services.

Similar to Direct, Express and Feeder Routes-Sub Urban Routes are also proposed for Lahore so that people living in suburbs of Lahore may come to Lahore and exit Lahore after their business. This facility will also reduce the rural

urban migration trends for Lahore.

4.1 Fare Integration

An integrated fare system refers to a single fare charge for a trip between two points in a public transport system, irrespective of the number of modes/services and operators involved in making the journey. This means that a passenger travelling from A to C via B using two different modes/operators will be charged a single fare for the journey instead of charging two separate fares i.e. one from A to B and the other from B to C. Integration of fares has social and financial benefits. This system requires Automated Fare Collection technology. It is proposed that an integrated public transport system for Lahore will include the following features:

1. Commuters can use only single fare to access different routes/services for the travel.
2. Fare Structures will be determined based on the levels of affordability of the public transport passengers.
3. Discounted or free transfers between different modes or lines for the passengers to enhance more public transport usage.

If this system gets running, then it will have several positive financial impacts on the urban transport industry of Lahore such as:

1. Increase in revenue due to increased public transport patronage.
2. Transparent revenue collection.
3. Reliable data can be used for financial modeling.
4. Protection of fare leakages/fare evasion.
5. Transparent subsidy mechanism through associated technology.
6. System cost reduction/optimization by eliminating route overlapping.

Proposed public transportation system integration for Lahore will have advantage of tracking/facilitating transfer passengers and delinking revenue from the bus operator. This facilitates planning short routes and imposing flat fare system. The flat fare is proposed so that to plan a system with simplicity where passengers know the fare to be charged for specific journey in advance and reduce operational complications. The short route arrangement helps to capture passengers travelling beyond 10 km through transfers. Table-6 shows the proposed flat fare for integrated public transport in Lahore. The combination of proposed flat fare and route length results in the fare to be charged in three stages as maximum two transfers are allowed.

Table 6: Proposed fare structure for P-T system integration in Lahore

Type of Operation	Flat Fare (PKR)
BRT Routes	20
Trunk Routes/ Express Routes	25
Feeder Routes	15
Sub Urban Routes	40 + 1/ km/ passenger

4.2 Physical Integration

Physical integration strategies focus on the physical elements of a mode or type of service. The physical integration means convenient transfer of passengers from one route to another which will allow short walking distance to move to a different public transport route or mode. Several key concepts should be considered in developing strategies for physical integration. The service plan and expected passengers demand should drive the design. For an integrated transport system in Lahore, different transport hubs in each vicinity were identified where major routes originate/terminate. These hubs allow transfer of passengers from one route to another without much walking and hence will reduce journey time.

To facilitate transfer of passengers, the stops for different modes e.g. bus stops, BRT stations and train stations are integrated providing short and direct transfers between different modes. Key design decisions for the public transport interchanges include the following:

1. Number of bays for passengers disembarking or embarking.
2. Adequate platform size to accommodate expected queuing and crowding.
3. Size of walkways and their routing to minimize the distance walked by the passengers.
4. Efficient fare collection for entering and leaving the system.
5. Passenger information about public transport services and way finding through the stations.

Figure 30: Elements of modal public transport integration in Lahore

Figure-30 illustrates the element of multimodal public transport integration in Lahore through an example of integration between feeder buses and Metrobus system.

4.3 Operational Integration

The operational integration aspects of planned system ensure that headway and operation hours between different public transport routes are coordinated. Each transport mode shall complement each other rather than compete. Punctuality, frequency, co-ordination of timetables, synchronizing arrival and departure times, operations management, safety standards and resource allocation must be consistent, uniformed and standardized to achieve that goal. Timetables of proposed routes must also reflect indicated on the timetables are achievable and acceptable during peak as well as off-peak

Figure 31: Proposed integrated public transport network of Lahore

4.4 Information Integration

Passenger information is an important component of service integration. All the public transport services operating in Lahore have designed their own travel information systems without any consideration of travel information of other modes. Passengers should be able to obtain information about all alternative forms of public transport easily and conveniently in one place. For an integrated public transport system, the passenger should get information about the route network and schedule of buses through:

1. Route information signs displayed at each bus stop, in buses and mass transit/interchange stations,
2. Customer help lines,
3. Websites and brochures.

5. Integrated Public Transportation System for Lahore

After complete data analysis and studying the possible integration techniques an integrated public transportation system for Lahore composed of 122 feeders, express and sub urban routes is proposed and shown in Figure-31.

Conclusions and Recommendations

Implementation of Integrated Public Transportation System is a major step in reforming the public transportation system of Lahore into a sustainable public transport system. Once implemented it will help in significant modal shift due to better facilities. An integrated public transportation system will enhance the public transport ratings which were collected during data collection. Government of Punjab can use this research for curbing the problems persisting in transport sector. Better transport facilities will ensure a significant modal shift and minimize the number of vehicles on roads which will have a positive impact on environment as well.

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