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Planning for Metro Transit Transportation System a simplified Approach: A Case Study of Ruwi City Center in Muscat

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Abstract— *Currently Muscat the capital city of Oman is suffering from many traffic and transported related problems. Some of the serious concerns are high vehicle ownerships, low occupancy in personalized vehicles and poor patronization towards public transportation systems. Ruwi is the City center and a major Central Business District in Muscat. More than one million commuters daily visit Ruwi City center for their day to day business. The common transportation related problems often reported by the citizens at Ruwi CBD, are traffic congestion, over speeding of vehicles, inadequacy of parking places and pedestrian safety. All such problems can be eliminated by providing efficient public transportation system by restricting the entry of personal vehicles and para transit. In this technical paper, panning and designing of public transit facility by metro transport facility is attempted by capturing land use and travel information of daily commuters at Ruwi CBD area. An extensive literature review is carried for establishing the bench marking while planning metro transit system. For this the CBD area is cordoned and divided into traffic analysis zones based on the land use characteristics. Travel information of the commuter is estimated through interviewing them at the CBD entry gateway points and work locations. Land use characteristics are captured through reconnaissance of the area and random inspection of land parcels. Land use Information captured through the Google images and physical verification of data of the selected sample land parcels helped in estimation and characterization of the land use. Questionnaire survey at the activity centers helped in estimation of total trips attracted by the land uses. Travel characteristics, derived through the personal interviews of the commuters, facilitated for the estimation of total trips. Trip factors for different land uses are derived. Total trips generated are quantified and is used in planning of Metro Transit facility at the Ruwi city center. Commuter circulation pattern for the metro transit is also scheduled. Also it is proposed to carry extensive literature for establishing bench mark while planning the transit system.*

Keywords— Public transit demand estimation, Planning for Metro Transit system, Travel patterns, Transit Planning at CBD.

I. INTRODUCTION

Public transit transportation system play an important role in infrastructure development of any Nation. Metro transit system is very important in cities where its citizens can be transported from one place to another by bus and train that is serving the community at regular times and fixed lines with quality standards. International experiences on Metro transit planning indicate the importance of organizing and developing public transport sectors as they positively reflect the cultural and architectural development enjoyed by different communities. Presence of well-developed public transport infrastructure reflects economic and social wellbeing of its Nation. In Muscat the capital city of Sultanate of Oman, the city center Ruwi is the major Central Business District where it's known, to house the large number of shops and commercial establishments, companies and government institutions and banks. Also it is an abode of 0.2 Million residents. Current land uses indicate the streets of Ruwi are suffering from varied traffic and transportation related problems. Hence for the CBD area at Ruwi city center needs to a facelift development for the sustainability which can be addressed by metro transit facility. Geographical location of the city center Ruwi is shown in figure-1

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Fig. 1: Location of Ruwi City center

Scope of the study:

The technical study in the current project is restricted its study in establishing the commuter travel characteristics and trip attractions of the land uses at Ruwi city center. The information collected, collated and is used in planning and designing of public transit system. (Metro).

Specific objective of the study:

- To study the travel characteristics of commuters at the Ruwi Center.
- To study the traffic circulation pattern of the commuters.
- To establish the mean trip length and desire patterns with in Ruwi City center area.
- Identification of suitable mass transit system.
- To establish bench mark study for referencing.

II. LITERATURE REVIEW

In the cities and urban areas the growing or increasing of vehicle trips by private cars is causes to air pollution, traffic accident and traffic congestion. The main factors that affect the use of public transport is the poor quality of service and travel time. (Advani, M. &Tiwari, G., 2005) The public transport system can be developed by studying travel time, travel costs and accessibility. In study two methods were chosen in the rapid public transportation system Metropolitan transport corporation (MTC) and mass rapid transit system (MRTS) through which the demand can be estimated in terms of services, costs, time and distance.(Muthukannan, M. & Thirumurthy, A., 2008) Prediction demand for metro networks from Heath The number of metro vehicles needed to accommodate commuters. In addition, Prediction the locations and number of stations and other facilities such as parking locations and customer services. (Ben-Akiva, M. and Lerman, S.R., 1985) Recent public transportation services are livelier in major cities, where demand assessment and general needs have been examined with a commuters survey conducted in Al-Batinah Governorate, Sultanate of Oman. The study showed that public transportation services are few and not commensurate with the amount of demand of commuters and there is excessive use of the accreditation in the mobility of private vehicles. Therefore, the development of transit transport will help solve congestion problems and other road problems. (Belwal, R., 2010) The quality of public transit transport system is very important, as the level of public transport services must be in accordance with specific quality assurance standards, which in turn increase demand for public transit transport. (Olivkova, I., 2011) Trunk-Branch (T-B) concept is a method or basis that can be applied in design and planning in the public transport system based on the results of studies and surveys. Which in turn make improvements and modifications by the administrators as they are considered as a guide to evaluate the improvement and development of public transit transport system services. (Montview, R. & Putcha, S.C., 2014) In the Tehran province of Iran, a study is concerned with estimating the demand of commuters on railways or public transportation system by using the method of Ordinary Least Squares (OLS). The results of this study indicate that the price variables in the public transit transport system had a negative relation with the demand of the public transit transport system. Or for the trip distance and income variables have a positive relationship with the public transport system. (Kohansal, R.M., 2013) In Mumbai, a study on the possibility of improving and developing public transit stations by taking surveys and analyzing the characteristics of passengers in stations. The study revealed that there were many characteristics of passengers that included access characteristics in terms of availability of passenger access routes and their comfort.(Raston, R. & Rao V.K., 2009) One of the fast growing cities in the world is the city of Dhaka, which is witnessing a significant growth in the numbers of population, where the urban expansion of the city of Dhaka is random. A study has been conducted in Dhaka city on the public transport system which plays an important role, but there are but there is poor planning, Public transport non-disciplined and lack of facilities for the public transport system. Moreover, in the study a new planning was developed to improve and develop the public transport system in an area that is integrated in terms of accessibility and administrative aspects of this system.(Niger, M., 2013) A study in Dhaka looking at the development and improvement of the different public transport system and its relationship with the public transport administration, where there is a lack of management of the public transport system which is negatively affected the maintenance of infrastructure, traffic, and the public transport system.(Hossain, M. , 2003)

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Past Work:

Ashalatha, R., Manju, V., and Zacharia, A.2013, in transportation planning, travel behavior, one of the important things that will help in analyzing the choice of the situation and reach an appropriate decision on the situation to be used in a range of circumstances. Since Thiruvananthapuram city where a large number of the population, where there is a lot of government institutions, organizations and private sector companies, research institutions and scientific institutions. Although there are many methods of transportation, but it needs another look because of the increased traffic jams so it was put to choose the travel behavior of passengers in this city, which is located in India towards the south side. In general This study aims to identify and search for factors that will contribute to the solution and develop Thiruvananthapuram city in terms of alleviating traffic congestion through proper analysis and forecasting demand for new means of transportation and to study the efficiency of public passenger behavior, where this study are limited for work trips only. In the study at the first a pilot questionnaire survey was done, where questions were concerned with the socioeconomic condition and it is characteristics such as gender, age, monthly income with the nature of work and the ownership of the car. In addition, questions were also about travel properties which included ways of transition from home to work with the reasons for choosing the situation in way of transition, travel costs, waiting time, travel distance and time of travel, etc. Moreover, in this study the multinomial logistic MNL model has been used, where it used on both intercity and urban mode choice models primarily. The multinomial logistic MNL used because it is easy in estimation and simple and simple mathematical form also, easy in interpretation, MNL model was used in the comparison between the number of two-wheeler users, car users, and users of buses. Where the results showed that some two-wheeler owners and most of the car owners do not use buses. It turned out that the bus users are from low income or middle income category, which may have a two-wheeled, therefore, the first choice are the buses. As for the owners of private vehicles, they see it as a more flexible and safety of the buses. From this study, the Thiruvananthapuram city needs a public transportation development, and provide the features, which attract owners of private vehicles to use the public transportation to reduce traffic congestion and pollution.

Navya, S. V. et al., 2013, the purpose of the study to develop a model help understanding the transportation of trips in the Thiruvananthapuram city to solve the chronic problems such the increase in accidents and pollution due to the increase f travel demand to the city and great stress upon transportation. Thiruvananthapuram city has two major stretches: Ulloor to LMS stretch and MG road (from east fort to LMS) stretch. MG road stretch was selected for the study and is consists of thirteen wards.

III. METHODOLOGY

A) Delineation study area at Ruwi the City Center and TAZ's

For establishing the traffic factors and travel parameters the city center area is area is cordoned off using the Google image as shown in the figure-2. Criteria for the delineation of the study area is based on the land uses characteristics and also it is circumscribed by sub arterial and arterial roads. The study area is further divided in to Traffic Analysis Zones (TAZ) based on the land use. Study area is divided into two TAZ as shown in the figure-2. The TAZ's are separated by a collector road. For capturing the traffic gate way entry points are identified and the vehicle counts and commuter information is captured through the personnel interviews using the questionnaire.

Fig. 2: Ruwi City center area cordoned from the regions

B) Identification of transportation parameters

For establishing the peak hour demand and there by the transit planning, entry gate way points are identified for the study area and are presented in the figure -3. These are the locations where the cordon surveys for traffic volumes and commuter travel characteristics are organized. These Gateway locations further help the transportation planners to plan the transit stations for metro facility and also the parking areas. Where the commuters can park their vehicle and make move in to the different land uses through public transit facility.

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Fig. 3: Gate Way Entry- Exit Locations at the project site Ruwi City Center

C) Land Use Quantification for Estimation of Commuters

For the study purpose City Center area is organized two TAZs based and geographical and land use characteristics. From the google images built up area and open areas are estimated. And also the categorization buildings into residential, public and commercial are established through personal verification and reconnaissance of the TAZ's. For characterization of land uses reconnaissance of the area is conducted and physical surveys organized in representative land parcel from each TAZ. For this 4 samples in TAZ-1 and 3 samples in TAZ-2 are identified for physical survey (Figure-4).

Fig. 4: Land Parcels for Physical Survey in TAZ's at the study area

D) Travel information of the commuters and willingness to travel:

Per capita trip rate and probability of the commuter ready to shift and willingness to travel is the prerequisite parameters for planning of public transit system. For establishing the travel characteristics of commuters travel information is established by conducting a questionnaire survey randomly at work places, at gate way entry-exit points. Travel information is collated to establish the trip rates which is used in transit planning.

IV. DATA COLLECTION AND ANALYSIS

To ensure a high-quality product, diagrams and lettering MUST be either computer-drafted or drawn using India ink.

A) Sampling Methodology

The method used for data collection in this study is random sampling method where respondents are chosen randomly from the target population who are visiting the city center. Every respondent have the equal probability to be interviewed without any bias but have the opportunity to be selected for only one time. In this case a random number generator is used simply to select respondents. Contrary to common belief selecting the right sample size is quite complex. it does not depend on the size of the target population. For example, whether the study area has 300,000 or 80 households, the sample size is constant. The right sample size depends on other factors such as the method used to select respondents, the number of subgroups and zones compared and measurement and sampling error.

For sampling procedure to determine the sample group for this study, the following equation was applied:

$n0 = Z2pq / e2 = 1.962 * 0.5 * 0.5 / 0.05 = 385$ (1)

Based on the equations the minimum sample size was obtained as 385.

where n0 = sample size for infinite population; Z = statistical parameter corresponding to confidence level (Z is 1.96 for 95% confidence interval); e = desired margin of error (adopted as 5%); p = hypothesized true proportion for population (adopted as 0.5 to account for the worst case). where n = sample size for finite population; N = population size.

Regarding the sample group chosen, the target population is the commuters who live in City center area as well as the people who visit Ruwi from the different parts of Muscat for their day to day business. In the current a sample size of 520 commuter sample was selected.

B) Commuter Survey and Format of the Questionnaire

To capture commuter travel information a questionnaire is designed incorporating the parameters which will go as inputs to the transit planning exercise. Survey is conducted at work locations and also on routes within the CBD areas. Altogether about 520 samples are collected.

Pictures: *Personal Interviews of the commuters at different places within Ruwi City Center.*

C) Survey Summary and Travel Characteristics

Main focus of the survey is to obtain the lead distance of

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the commuter after reaching the entry points of Ruwi City Center and willingness of the commuter to shift from personal mode to public transit mode. The data collected from 520 sample survey is collated and coded and processed using the standard software SPSS. Results are summarized in the following table-1 and figure -5. During the survey it is revealed that more than 75% of the commuters expressed their willingness to shift mode if state of art metro transit facility is made available.

Table.1: Distribution of commuters by lead distance

Sl.No	Lead Distance	Average Distance	No of Respondents	%	f*mean distance	Average Distance Km
1	Up to 2Km	1	72	14%	72	4.69
2	2-4 Km	3	120	23%	360	
3	4-6 Km	5	198	38%	990	
4	6-8 Km	7	76	15%	532	
5	8-10Km	9	54	10%	486	
			520	100 %	2440	

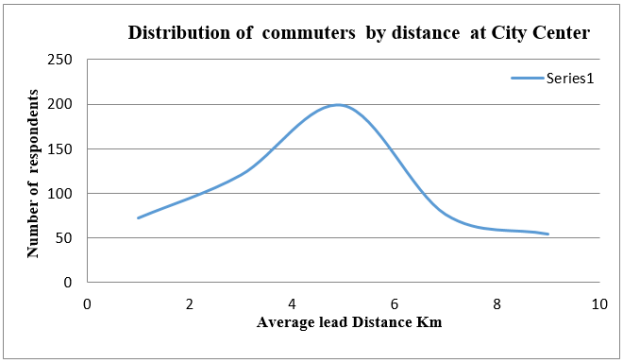

Fig. 5: Frequency Distribution of Commuters for Lead distance at Ruwi City Center

D) Entry –Exit of the commuters at the Ruwi City Center Gateway Points:

From the Vehicle Volume count at the Gate Way entry and exit points and also from the commuter survey, perceptions of the commuters and distribution of commuters is captured and mapped. Geographical distribution of commuters is shown in the figure-6 and Table: 2

E) Entry –Exit of the commuters at the Ruwi City Center Gateway Points

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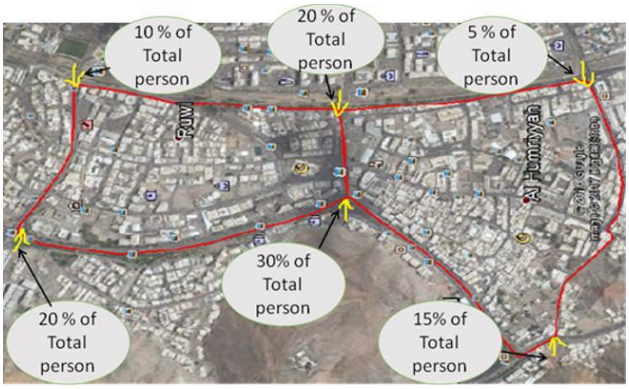

Fig. 6: Geographical distribution of traffic entry at the Gateway points to City Center

Table.2: Vehicle Volume counts at the Ruwi Gateway Entry Points

Gate Way	Time	Small Car	Big Car	Total PCU
I	7.00-8.00	854	348	1376
	8.00-9.00	942	514	1713
II	7.00-8.00	1642	785	2820
	8.00-9.00	1746	1041	3308
III	7.00-8.00	412	185	690
	8.00-9.00	502	241	864
IV	7.00-8.00	1678	743	2793
	8.00-9.00	1745	1042	3308
V	7.00-8.00	2475	1048	4047
	8.00-9.00	2541	1426	4680
VI	7.00-8.00	1484	415	2107
	8.00-9.00	1487	846	2756

Data presented in the table 6 gives an idea of entry of vehicle in to Ruwi CBD through different entry points.

All together there are more than 16000 cars are entering in to Ruwi City center during the peak hours of a day. If these vehicle's entry is stopped at the gateway points and allowed to park at the proposed transit locations Ruwi would become totally traffic free zone and many of the traffic related concerns would be solved.

F) Land-use characterization at Ruwi the City Center

An acknowledgement section may be presented after the conclusion, if desired. Land use of the study area is quantified using the Google maps and verified for authentication of the calculations through physical inspection of the land parcels on random basis. Examination of the Google maps reveal that the total area of TAZ-1 is 750,818 m2 with number of buildings 382 and for TAZ-2 is 911,224 m2 with number of building

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787. And for physical examination of the TAZ's sample land parcels from each zone covering a minimum area of 400 m2 is selected. The data collection from land parcel areas from the TAZ's to arrive the tentative estimates of number of buildings and the type of buildings. Figure-7 depicts the sample selection land pockets in the TAZ.

Fig. 7: Land pockets in TAZ's for Physical verification of the Land Use

Physical examination of land parcels in TAZ-1 and TAZ-2 gives the general idea of FSI of the buildings and also facilitate in estimation of gross area of the building foot print. Building topology in the selected land pockets is presented in the figure-8.

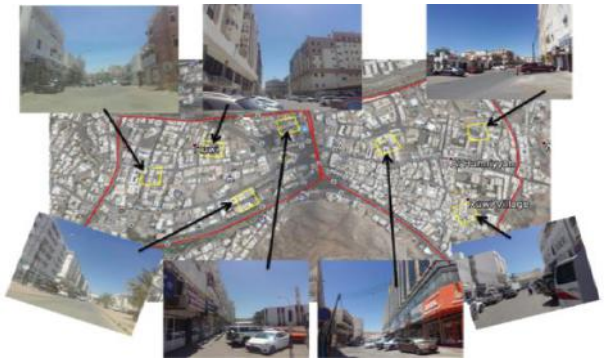

Fig. 8: Physical survey of the selected land parcels in the TAZ

From the reconnaissance of the study area and physical inspection of the sample areas the Floor Space Index (FSI) in the study area is found to be 4. Moreover, Open area and Road area together is equal 200 m^2. Also it is observed that 50% of the area is under open space or roads and 50% of the area is allowed for construction activity.

Gross Built-up Area = Built-up Foot Print Area x Floor Space Index (FSI)

Gross Built-up Area for each of the land parcels would be equal to 200 x 4 = 800 m^2

G) Trip Attractions of Different Land Uses:

Land use analysis of the TAZ is carried and presented in the tables- 3&4. Number of building in each of the TAZ's are also captured on random sample basis and analyzed for characterization of land use and presented in the table-5. Total number of building in TAZ-1 and TAZ-2 are 382 and 787 respectively. For the estimation trips entering or leaving the city center area, Quick Response Technique (QRT) is used for quantification of the trips. Every parcel of land would attract or produce certain number of trips based on the type of land use. To find trip attraction or production rates of each land use, discussions are held with the commuters at business establishments, commercial land uses , offices etc based on the interviews the trip factors have been arrived and presented below tables 3-7.

Table.3: Land use Analysis of the sample Area

Description	**Area m2**	%
Road Area	**130**	32.50%
Open Area	**120**	30.00%
Built Up Area	**150**	37.50%
Area of Zone Sample	**400**	**100%**

Table.4: Land use Analysis of the Study Area the City Center

Sl.No	TAZ	Geographical Area m^2	Open area m^2	Area Under Roads m^2	Built-up area m^2	Grass Floor Area m^2
1	TAZ-1	750818	262786.3	225245.4	262786	1051145
2	TAZ-2	911224	318928.4	273367.2	318928	1275714
	Total	1662042	581714.7	498612.6	581715	2326859

Total number of buildings situated in both the TAZ's are counted using Google maps, classification of buildings captured are presented in the table-5 to table-7

Table.5: Building Topology of selected land parcels in TAZ-1 and TAZ-2

TAZ	Sector	**No. of Commercial Building**	**No. of Residential Building**	**No. of Public Building**	**Total Buildings**
I	1	**34**	**27**	**1**	62
	2	**20**	**19**	**1**	40
	3	**16**	**0**	**0**	16
	4	**20**	**24**	**0**	44
	Sub Total	90	70	2	162
II	1	**37**	**0**	**0**	37
	2	**25**	**27**	**2**	54
	3	**28**	**36**	**1**	65

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	Sub Total	90	63	3	156
	Grand Total	180	133	5	318

Table.6: Composition of the Buildings at the City Centre, Ruwi Muscat.

Type of Building	Number	%
No. of Commercial Building	171	54%
No. of Residential Building	133	42%
No. of Public Building	14	4%

Table.7: Distribution of land uses at the City Centre, Ruwi Muscat

Land use	**%**
Area Under Public	93074.35
Area Commercial	1256504
Area Residential	977280.7
Grass Built-up Area	2326859

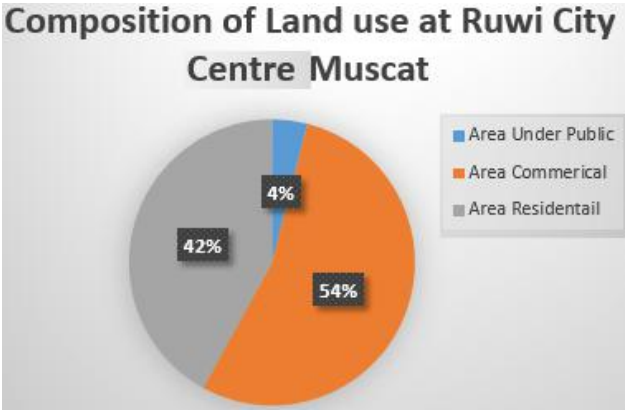

Fig. 9: Composition of Land use at Ruwi City Center

H) Trips Generated at different land uses:

Different land uses generate different trip rates. For this sample surveys conducted at the work places, residential localities within the city center area are collated and results are presented below in table: 8

Table.8: Trips generated from different land uses and trip rates

Sl. No	Type of Building	No of units selected	Gross Floor Area of all units	Appox Number of Visitors in a day	Visitors per Sq.M
1	Office Building	4	1200	60	0.05
2	Commercial Untis	40	1450	855	0.59
3	Residential	20	2400	412	0.17
			5050	1327	0.26

Derived trip rates at different land uses are used in estimation of the trips generated per day at different land uses at Ruwi city center and are given in table -9. .

Table.9: Quantification of trips from different land uses at City Center

Land use	Public	Commercial	Residential	Total
Trip Generated per Sqm	0.05	0.59	0.17	0.26(Average)
Gross Land use	93074	1256504	977281	2326859
Number of Trips Generated in a Day	4654	740904	167769	913324

I) Planning of Metro Transit Transport System

Public transit system is vital for the sustainability of CBD areas where the citizens can live and do their business incompatible with the natural resources and socio economic environment. In general public transit transportation systems for a given metropolitan area, typically comprising buses, subways, and elevated trains. The transit systems offer large benefits to its commuters and require a variety of transportation infrastructure in terms of pedestrians pathways, parking facilities, bus bays , transit stations, public utilities, intelligent transportation systems and integration of the system components to its land uses. It is estimated the number of trips generated at Ruwi CBD area would be 0.9M trips a day. Assuming at least 25% of people would be opting for the transit facility immediately with a peak hour factor of 7%, number of trips generated would be about 15,750 trips in both the directions. Trips generated per hour per direction would be 7875 PPHD (Passenger per Hour per Direction).

Assumptions while planning a Metro Service:

Benchmarking studies and literature review suggested the following assumptions and presented below:

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- Maximum average block to black distance of a metro station would be 2.0 Km.
- Average velocity of transit metro mode would be 40Kmph.
- Maximum permissible waiting time for the commuter at the transit station for the commuters would be 10minutes.
- Maximum capacity of a coach/compartment would be 120 passengers.
- A metro service consist of four coaches with a capacity of 480 passengers PPHD
- In an hours' time about at any given point over the en route about 3000 passengers would be using the transit facility in each direction.

Giving the derived inputs and assumptions transit planning facility is suggested and given in the figure-9

Fig. 10: Planning of Public transit transport system (metro) at Ruwi CBD area

The figure-10 shown is suggested metro transit transportation system for the city center area at Ruwi. While planning the transit system other transportation infrastructure services like metro stations bus stations, parking areas public utilities along the route plan for each transport system is also indicated. Proposed transit system and services are shown in the figure-11

Fig. 11: Metro Transit System with all infrastructure Services

V. RECOMMENDATIONS AND SCOPE FOR FURTHER WORK

Since public transit transport system is very important for the development of cities. There is a need for the development of efficient and affordable transit transportation system for which Metro is latest option. Most of the GCC countries are going for metro facility with phase wise development for its implementation. The success of metro transit largely depends on its accessibility and its integration with its land uses and catchment area. Before the implementation of such facility, large scale studies need to be initiated for station area development, parking, public utilities and allied services.

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