A Simulation-based Optimization Approach of the Public Transport Network for A Multiple-core City, Kabul

Naimatullah Shafaq Rahmatyar

Department of Civil Engineering
National Institute of Technology Rourkela

A Simulation-based Optimization Approach of the Public Transport Network for A Multiple-core City, Kabul

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by

Naimatullah Shafaq Rahmatyar

(Roll Number: 215CE3251)

based on research carried out

under the supervision of

Prof. Ujjal Chattaraj

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Department of Civil Engineering
National Institute of Technology Rourkela

Department of Civil Engineering
National Institute of Technology Rourkela

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Certificate of Examination

Roll Number: *215CE3251*
Name: *Naimatullah Shafaq Rahmatyar*
Title of Thesis: *A Simulation-based Optimization Approach of the Public Transport Network for A Multiple-core City, Kabul*

We the below signed, after checking the thesis mentioned above and the official record book (s) of the student, hereby state our approval of the thesis submitted in partial fulfillment of the requirements of the degree of *Master of Technology* in *Civil Engineering* at *National Institute of Technology Rourkela*. We are satisfied with the volume, quality, correctness, and originality of the work.

Ujjal Chattaraj
Principal Supervisor

Prof. Mahabir Panda

Prof. Prasanta Kumar Bhuyan

External Examiner

Head of the Department

Department of Civil Engineering
National Institute of Technology Rourkela

Prof. Ujjal Chattaraj

May 22, 2017

Supervisor's Certificate

This is to certify that the work presented in the thesis entitled *A Simulation-based Optimization Approach of the Public Transport Network for A Multiple-core City, Kabul* submitted by *Naimatullah Shafaq Rahmatyar*, Roll Number 215CE3251, is a record of original research carried out by him under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Technology* in *Civil Engineering*. Neither this thesis nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

_____
Ujjal Chattaraj

Dedication

Dedicated to my respective parents, and grandparents.

Signature

Declaration of Originality

I, *Naimatullah Shafaq Rahmatyar*, Roll Number *215CE3251* hereby declare that this thesis entitled *A Simulation-based Optimization Approach of the Public Transport Network for A Multiple-core City, Kabul* presents my original work carried out as a postgraduate student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections "Reference" or "Bibliography". I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

May 22, 2017
NIT Rourkela

Naimatullah Shafaq Rahmatyar

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NIT Rourkela

Naimatullah Shafaq Rahmatyar
Roll Number: 215CE3251

Abstract

Kabul is the capital city of Afghanistan with the massive expansion of population since 2001. By 2025 Kabul's population is projected to increase by $769,539$ inhabitants. This growth will not be only in the inner city, but with higher growth rate in the urban-cores, affecting the city structure morphologically as well as functionally. Before 2001, Kabul was a monocentric city with a dominant inner city; Nowadays due to the rapid growth of population, Kabul is becoming morphologically polycentric city which needs transformation to a functionally polycentric shape. The fact that Kabul is becoming a polycentric city $(with\ strongerurban - cores)$ makes it necessary to adapt its public transport network to this fact. Nowadays, around 58% of the trips between urban-cores are made by cars causing more congestion, emission, and high user cost. To overcome this problem, it is most likely to improve the public transport system capable of attracting more people to use it rather than cars. So, the idea attained here is to propose a new line linking the urban-cores to each other using the Headway-based Assignment procedure of the $VISUM$ macro simulation software. This new line pretends to strengthen the urban-cores and create a more polycentric public transport network. Two alternatives will be studied as $Alternative - 1$ follows the present planning of the lines in city and urban-cores with buses that have a distance between stops of around 400 meters. The $alternative - 2$ shows planning for polycentrism, with the distance between stops around 800 meters and a speed higher than the alternative-1. Furthermore, for each alternative different routes will be studied with respect to the base year 2016, and the target year 2025. Finally, all the alternatives and sub-alternatives will be compared among themselves and with the reference scenario to find the one which would improve the multi-core structure of Kabul effectively.

***Keywords*: *Kabul*; *Multiple-core city*; *Public Transport Network*; *Headway-based Assignment*; *Comparison of alternatives*.**

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Chapter 1

Introduction

1.1 Background

Kabul is the capital city of Afghanistan located in the north-east side of the country, with the total planned area of $1022.7km^2$14 times that of 1964 consisting of 22 districts (wards), average elevation from mean sea level of 1800 m, a projected population of up to $6,271,711$ inhabitants in the year $2025(JICA, 2009)$ and $(CSO - A, 2016)$. Due to rapid urbanization, Kabul ranked as the $5th$ rapid growing city of the world with the increase in population from approximately $380,000$ in 1964 to almost $5,502,172$ inhabitants in $2016(CitymayorsStatistics, 2016)$. From 1962 to 2008 Kabul has always been fluctuated from different aspects of urban development. Still, it is functionally a monocentric city, but due to rapid growth in population and urbanization, it is desired to be transformed to a multiple-core city $(JICA, 2009)$. Nowadays people living in Kabul are always suffering from the inadequate assignment of the public transport to connect the suburbs to each other and to the city center. Even due to more congestion and less accessibility to the public transport the people are willing to either walk (for some kilometers) or to travel by car (with costs more than four times that of bus fare).

The population, as well as territory of the Kabul City, expanded steadily since 1775 became the capital of Afghanistan. Since early 20^{th} century, the city has experienced rapid growth of population and workplaces. Unfortunately, due to different political turmoil and war from 1992 to 2001, the city development in the various sectors has been sluggish. During the said period, the existing infrastructure of the city was severely damaged. Since 2001, the government and people of Afghanistan are making so many efforts for reconstruction and improvement of the Kabul City infrastructure. These efforts are for nothing but to further facilitate the urban life. However, due to lack of observed data sets and proper research in each sector especially in the public transportation sector, the daily trips for different purposes are still not properly satisfied. Since 2001 due to the car became as the mean of public transport, a rapid increase of the urban development occurred in the suburbs. This is known as suburbanization, an outer development with dense urban-cores. Now, Kabul is rapidly growing its population as well as workplaces. The of Kabul will increase by $769,539$ inhabitants in 2025. This growth will not be only in the inner city, but with the greater rate in

the newly established districts, Figure 1.1 shows it. The employment at workplaces has also been increased. This increase is more for the new districts rather than the central part; Figure 1.2 shows it. It means the city is getting expanded and many opportunities are provided outside the city center.

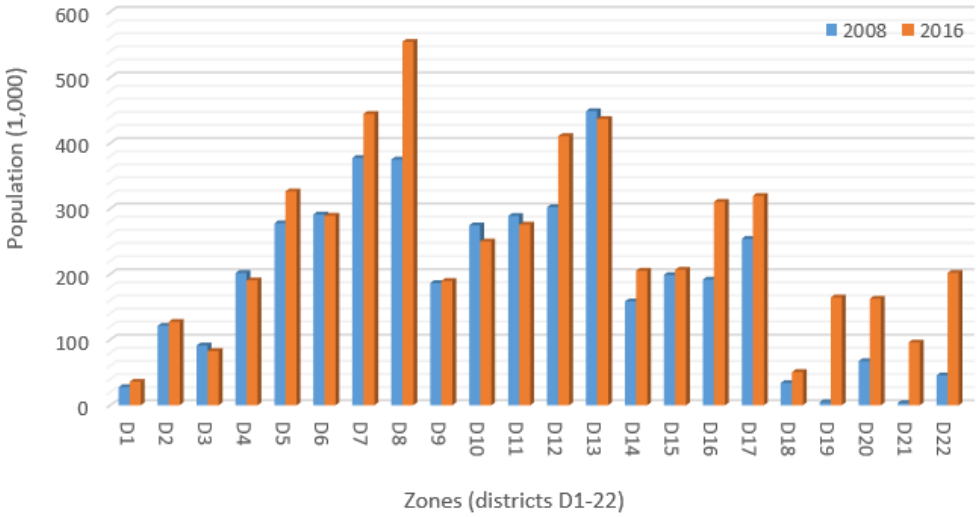


Figure 1.1: Population increase in different districts of Kabul city

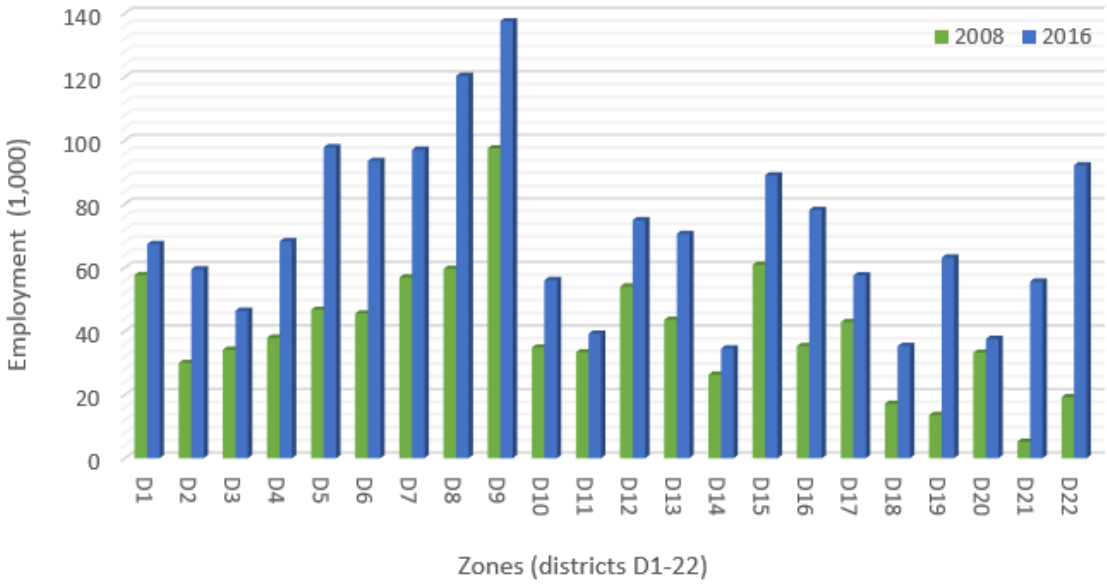


Figure 1.2: Employment increase in different districts of Kabul city

Kabul nowadays requires immediate needs of the urban transportation system to be fulfilled, also proper development and the planning strategies for future mid and long

term. Lack of such planning has created daily transport problems in Kabul i.e. congestion, poor accessibility to public transportation, more travel and waiting time, emission, lack of parking facilities, and so on. Before 2001, Kabul was a monocentric city with a totally dominant central urban-core. The main activities, like many workplaces, cultural offering and entertainment were concentrated in the inner city. Up until the early 21^{st} century, Kabul is synonymous with the inner city. It is until the public transport is not improved when urban development could spread to the suburbs, at first slowly with bus lines and Bus Rapid Transit System.

The reason that Kabul is becoming a polycentric city is the increases in population which need land for constructing the building, transport infrastructure, drainage and technical supply systems. The city must be developed such that the parts (structures, water structure, green structure, urban and transport infrastructure) cooperate, contribute and complement each other. As far as transportation is concerned, it is needed to strengthen links between the urban-cores to create efficient public transport.

1.2 Development of the city

For the purpose of Kabul city development, many efforts had been made, which includes the provision of different master plans since 1962 shown in Table 1.1. The land use and territory boundary for Kabul city third master plan are shown in Figure (1.3 & 1.4).

Table 1.1: Kabul city master plans since 1962

Sl#	Item	Year		Population		Area (km^2)
		Base	Target	Base Year	Target Year	Target Year
1	1st master plan of Kabul City	1962	1987	380,000	800,000	237.8
2	2nd master plan of Kabul City	1970	1995	-	1,416,000	299.0
3	3rd master plan of Kabul City	1978	2002	-	2,000,000	323.3
4	4th master plan of Kabul City	2011	2025	-	7,698,000	1,022.7

Figure 1.3: Land use plan of Kabul city third master plan.1978

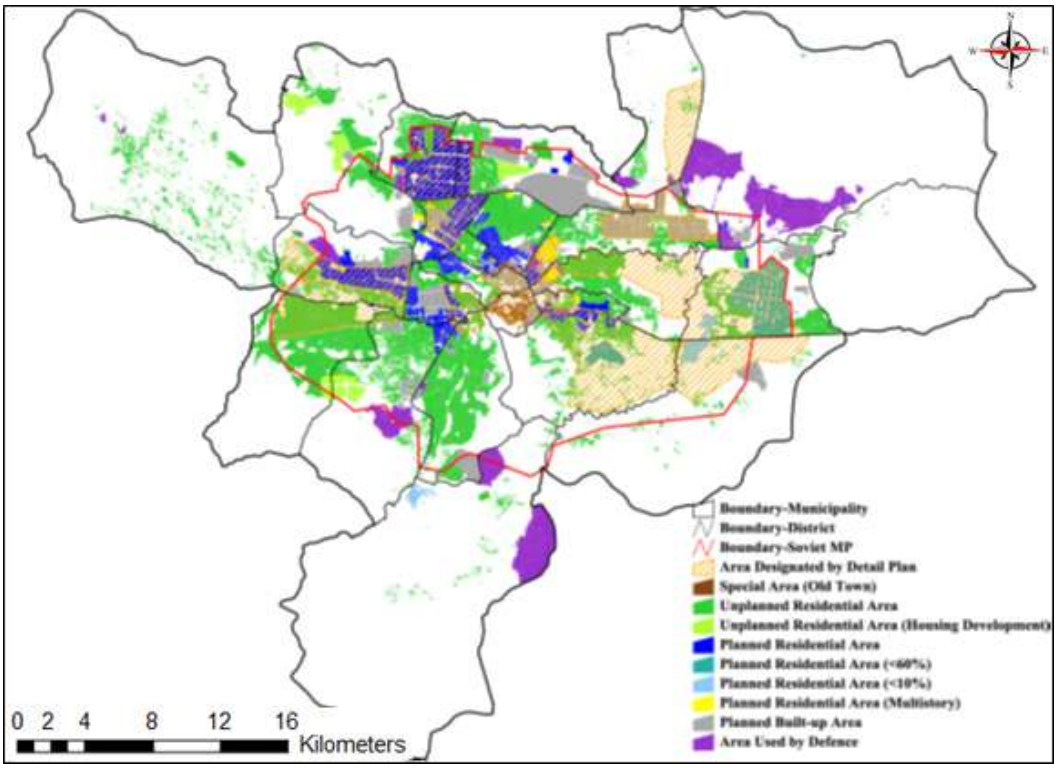


Figure 1.4: Distribution of the planned and unplanned residential Area in Kabul third master plan

Kabul city in the 20^{th} century started to provide affordable housing to people. The strategy was to optimally separate land for recreation and areas for developing purposes. Modernistic ideas inspired this division between business, work and upgrading the existing unplanned areas. In the following years, a comprehensive city plan was created to plan the new suburbs along the 105 km ring roads around the city. The new suburbs had commercial as well as social cores. The public transport system was developed based on a network of trolleybuses and Millie bus (National Bus) lines to provide people a way to go to work in the inner city or the workplaces. The trolleybus line was connecting only the eastern parts to the western and central parts of the city. Still, more routes were not covered by it. Figure 1.5 shows the route plan of Kabul city trolley bus line ($1979 - 1991$).

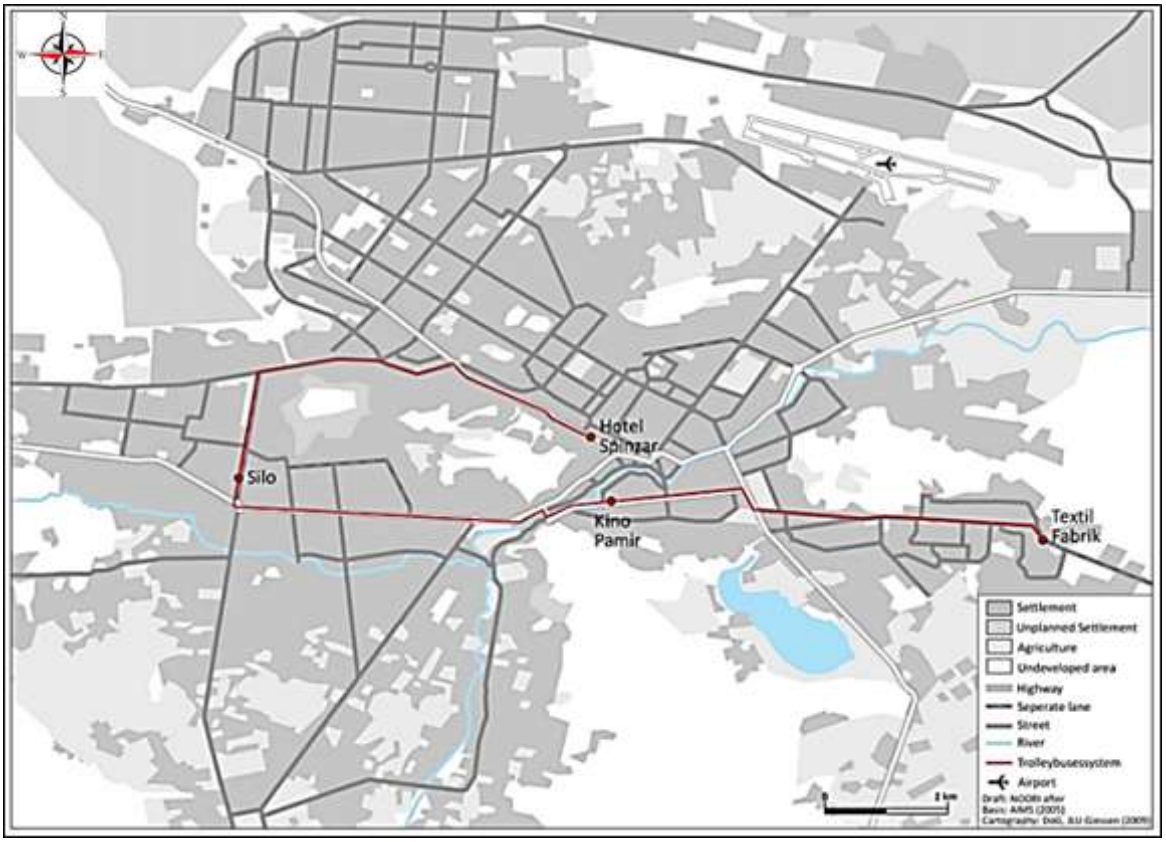


Figure 1.5: Kabul city trolleybus route plan 1979-1991

The trunk road network proposed by the Kabul city Third Master Plan was analyzed and adopted as much as possible to respect the neighborhood units defined by it. Those already constructed trunk roads were kept as given condition. The alignment of unconstructed planned roads is also respected in case of preparation of some detail plans on areas less or unpopulated. As a result, in the southwestern part of Kabul city, the configuration of the future network is modified largely, due to the development of private housing estates as well as urbanization by the construction of spontaneous housing.

The planning condition of the trunk road network reflecting the road network purposed by the Kabul Third Master plan is shown in Figure 1.6.

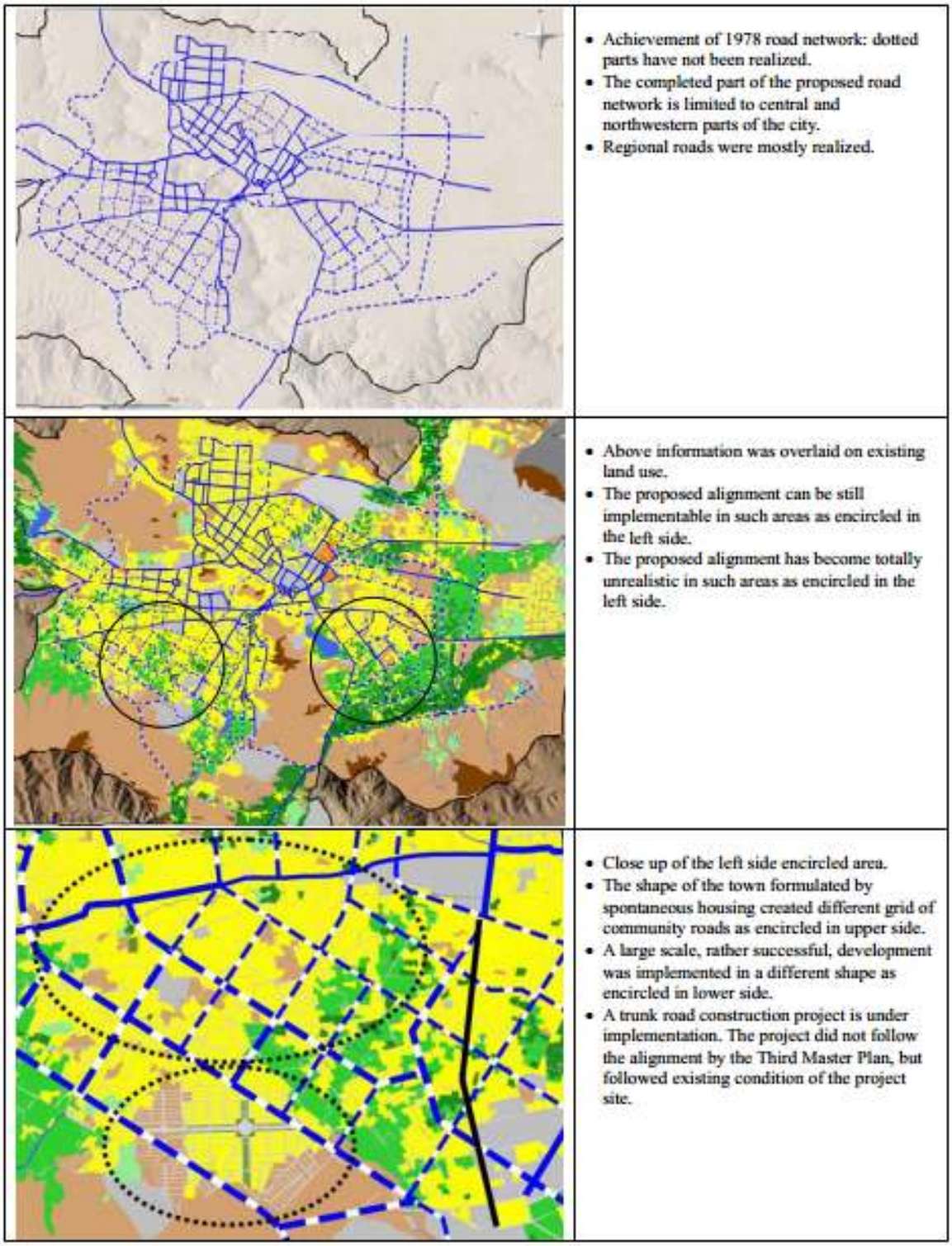


Figure 1.6: Roads network condition proposed by Kabul third master plan

1.3 Current Plans

1.3.1 Kabul City Master Plan (Revised 2011)

From 2001 onwards the Kabul city's population has increased dramatically, which made more needs for a new planning of the city. For this purpose, Government decided to revise the from the total planned area of $275km^2$ ($22\ zones$) to $1022.70\ km^2$ ($26\ zones$) with the technical cooperation of Japan International Cooperation of Japan $(JICA)$ for the target year of 2025. $Zone1-22$ is known as Kabul old city, while $zone23-26$ is known as Kabul new city. Hence currently, Kabul City has its fourth master plan the i.e. Kabul city's revised master plan (2011) for the target year of 2025, planned area of $1022.7Km^2$ consisting of the Kabul Municipality's entire territory ($22districts$), and Kabul new city.

1.3.2 Capital Region Independent Development Authority (CRIDA)

Deh Sabz City Development Authority (DCDA) is the authority for implementation of the master plan for Kabul new city from 2006 to 2016. In order to make the capital, Kabul capable of providing the base for more economic activities as well as modern and affordable urban life for the residents in long term, the government of Afghanistan officially renamed the DCDA to Capital Region Independent Development Authority (CRIDA). The total area of Capital Region (CR) is $7735km^2$ which includes the area shown in Table 1.2. Figure 1.7 shows the boundaries of the CR.

Table 1.2: The areas located in the Capital Region (CR)

No.	Name	District/city	Province/city
1	Bagrami	District/city	Kabul city
2	Char Asyab	District	Kabul city
3	Deh Sabz	District	Kabul city
4	Estalif	District	Kabul province
5	Farza	District	Kabul province
6	Guldara	District	Kabul province
7	Kalakan	District	Kabul province
8	Khak-i-Jabar	District	Kabul city
9	Mirbacha Kot	District	Kabul province
10	Mosahee	District	Kabul city
11	Qara Bagh	District	Kabul province
12	Shakardara	District	Kabul province
13	Surubi	District	Kabul province
14	Paghman	District	Kabul city
15	Charikar City	City	Parwan province
16	Jabal Siraj	District	Parwan province
17	Saidkhil	District	Parwan province
18	Bagram	District	Parwan province
19	Maidan Shahr	City	Maidan Wardak province
20	Mahmud Raqi	District	Kapisa province
21	Kohistanat	District	Kapisa province
22	Pul-i-Alam City	City	Logar province
23	Mohammad Agha	District	Logar province
24	Khoshi	District	Logar province

Figure 1.7: The Capital Region boundaries

1.4 Needs for Transformation of Urban Structure

Figure 1.8 shows the transportation desired lines overlay on the existing urban area in 2008. From the Figure 1.8, it is clearly seen that the transport desire lines in 2008 are mostly concentrated in the center of the city, while most of them cross the natural barriers i.e. hills. The transport desire lines in 2016 follow the scenario much stronger than that of 2008. So, the demand for transportation will further generate across the natural barriers mentioned above, if the city keeps the trend of the existing urban structure characterized by the concentric hierarchy of urban functions.

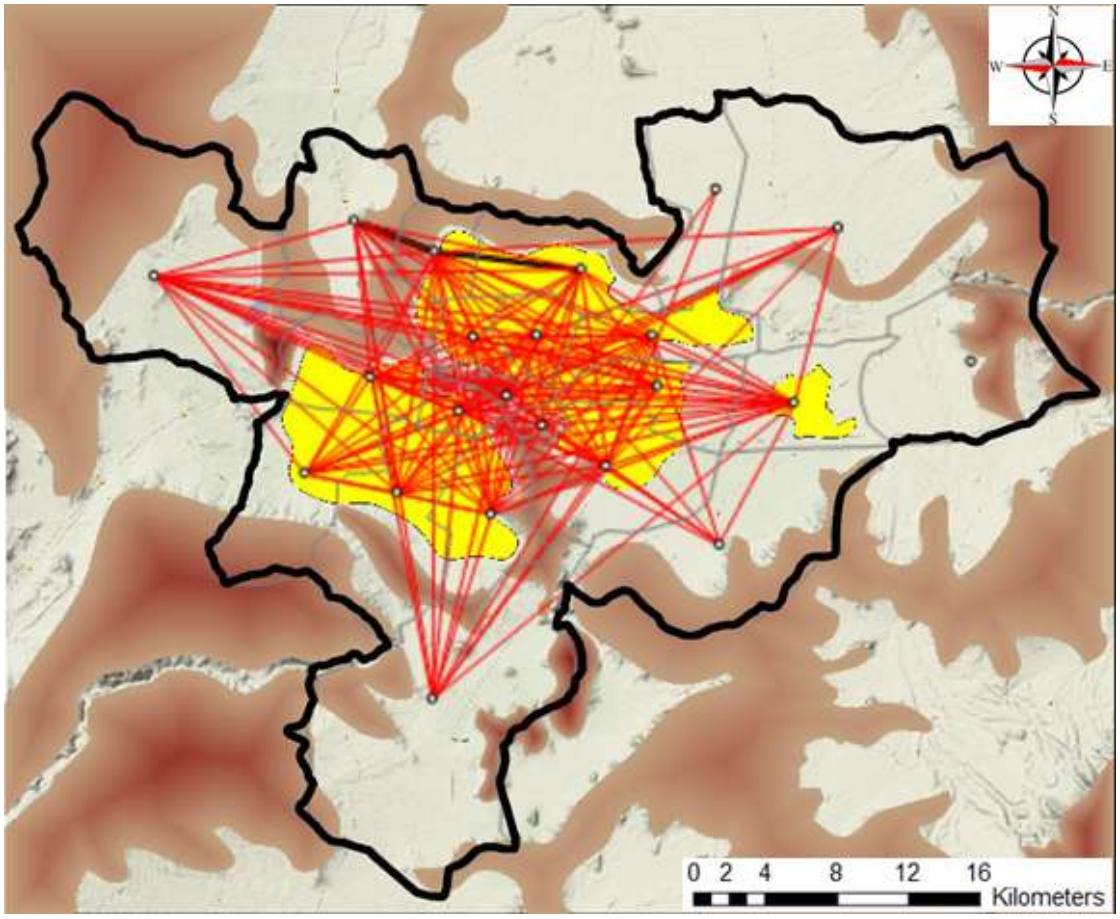


Figure 1.8: Desire Lines of 2008 over Existing Urban Areas in Kabul City

To overcome the inherent disadvantage mentioned above, the Kabul City urban structure needs transformation from monocentric structure to a more polycentric structure, by introducing some sub-centers for each urban-core. This transformation of the city structure will help the Kabul City urban structure to a more decentralized shape which consists of the self-sufficient urban-cores. Each particular sub-center needs good access to themselves and the city center from different parts of its coverage area, while such access is required to be maintained with the sub-centers developing in the Kabul New City. The image of self-sufficient urban cores of Kabul City by introducing the sub-centers can be seen from Figure 1.9.

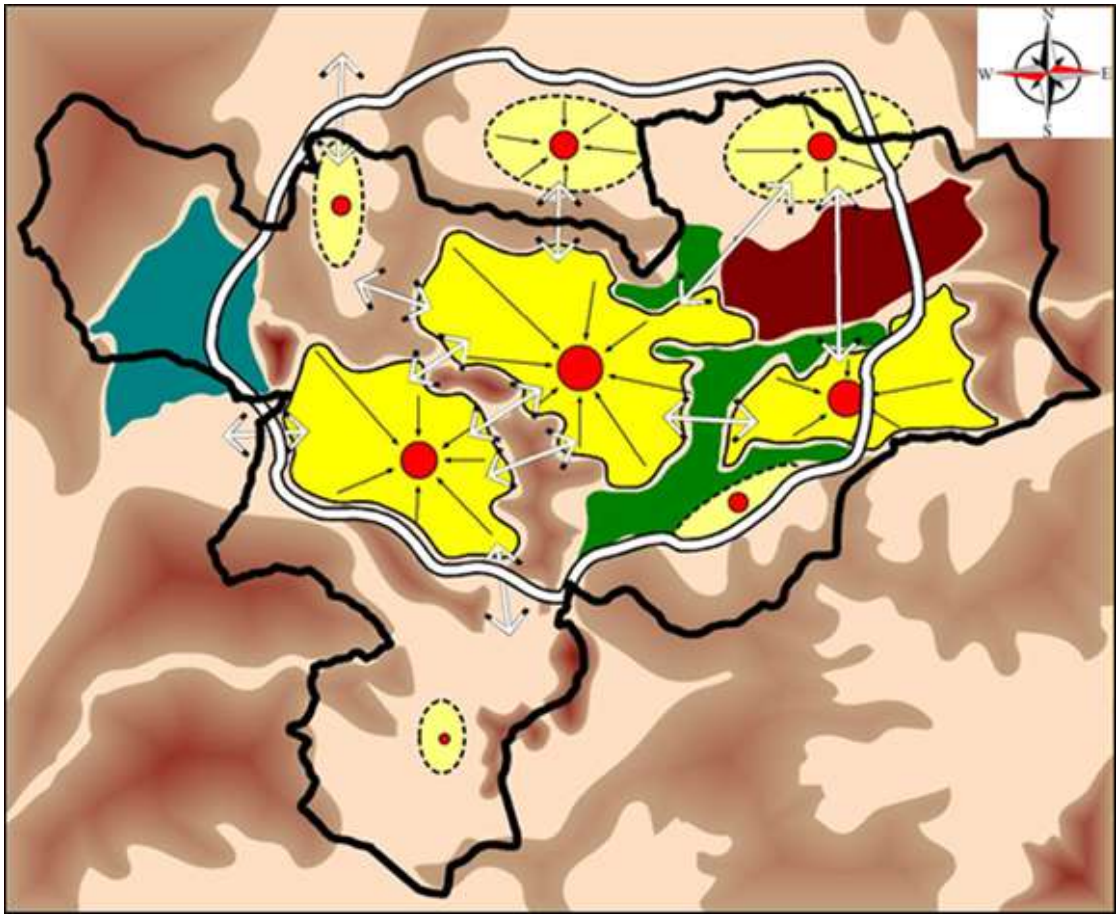


Figure 1.9: Image of Self-Sufficient Urban Enclaves

1.5 Objectives and scope of work

1.5.1 Problem statement

As stated earlier, Kabul has faced the huge challenges in its urban structure due to the destruction of its infrastructure because of war $(1989 - 2001)$. The population growth has been occurred rapidly since 2001, while the infrastructures especially transportation infrastructure is still not adapted to this fact. Most of the commuting trips between urban-cores as well as the city center are made by private cars (a huge challenge from the economic, and environmental aspects). Even nowadays car is known as the mean of public transport. Trips for the job, school, and etc. are mostly done by other modes of transport rather than public transport. The main reason, that why people don't use public transport (use other modes) is less accessibility to the public transport, public transport without predefined frequencies/schedules of the lines, less integrity between the different modes of transport, centrally concentrated transport system (urban-cores are not connected to each other), proper stop points/stations, affordability, security and safety, and etc. Still, Kabul is functionally a monocentric city, while it is morphologically polycentric. So, it needs transformation from monocentric to polycentric. The urban-cores are increasing their populations and number of

workplaces. They emerge from older cores that have grown, also from new sub centers that appeared because of being a transport network nodes.

1.5.2 Problem formulation

To overcome the challenges stated above, Kabul needs a transformation in its urban structure from monocentric to polycentric shape. This change needs the urban-cores to be strongly connected between themselves and the inner city. Here is the public transportation plays the key role. The commuting trips are habitually made by car, and we want this habit should be changed to the trips by public transport. It is not possible, but to provide an attractive transportation system. The public transport will not be attractive to the users, and environment-friendly until unless to provide affordability, accessibility, secure and safety, integrated, and the lesser harmful to the environment.

A proper development of the urban-cores is needed to make them an alternative to the inner city, which nowadays has massive congestion problems. So, trips to the city center should be changed to trips between suburbs.

1.5.3 Purpose of the study

The purpose here is:

- To research about Kabul's actual public transport network,
- the growth of the population and workplaces, and
- the future network.
- To improve the connections between urban cores with the proposal of a new line which crosses the most important suburbs.

1.5.4 Objective

Followings are the objective of this study:

- To understand what the situation of public transport network of Kabul is today and what will be in the future.
- To propose a new line which can strengthen the polycentric structure of Kabul.
- To establish the equation for impedance by which VISUM simulates which route to choose.
- To minimize the Perceived Journey Times (PJTs) for each zone using VISUM tool.

- Testing of different alternatives to find the one which would help to strengthen the Kabul multiple-core structure.
- To determine the capacity of the line.

Approach

The steps to be followed in this thesis are:

a) Study about monocentrism and polycentrism in Kabul and other cities around the world.

b) Collection of information about the distribution of workplaces and population in Kabul city, the current situation of the most important urban-cores, today's public transport network in Kabul and the future plans.

c) Test of different scenarios to see if there are particular important measurements that support the multiple-core structure.

d) Proposal of a chosen solution among many alternatives for present and the future scenarios, which will be studied meticulously.

Scope of the work

From the screen line survey conducted in $2008(JICA, 2009)$, the Jadayi Sehi Aqrab road shows the highest volume of traffic compare to other roads i.e. Bagh Bala, and Gozar Gah roads. So, the scope of work will be to study the route from Company Chowk to Bot Khak of Kabul city which includes the most congested road of the Kabul city as stated above. From another hand, the developing districts of Kabul city i.e. $district 18, 19, 20, and 22$ are located on the above-mentioned route. Furthermore, most of the important districts i.e. $district 1, 2, 3, 5, 8, 12, and 16$ which highly contribute in trip generations and attractions are also located on this route. Also some other important zones i.e. $zone\ 6, 7, 13, 14$, will be served by this route with the maximum of one transfer. The road network for the buses in Kabul city is illustrated in Figure 1.10.

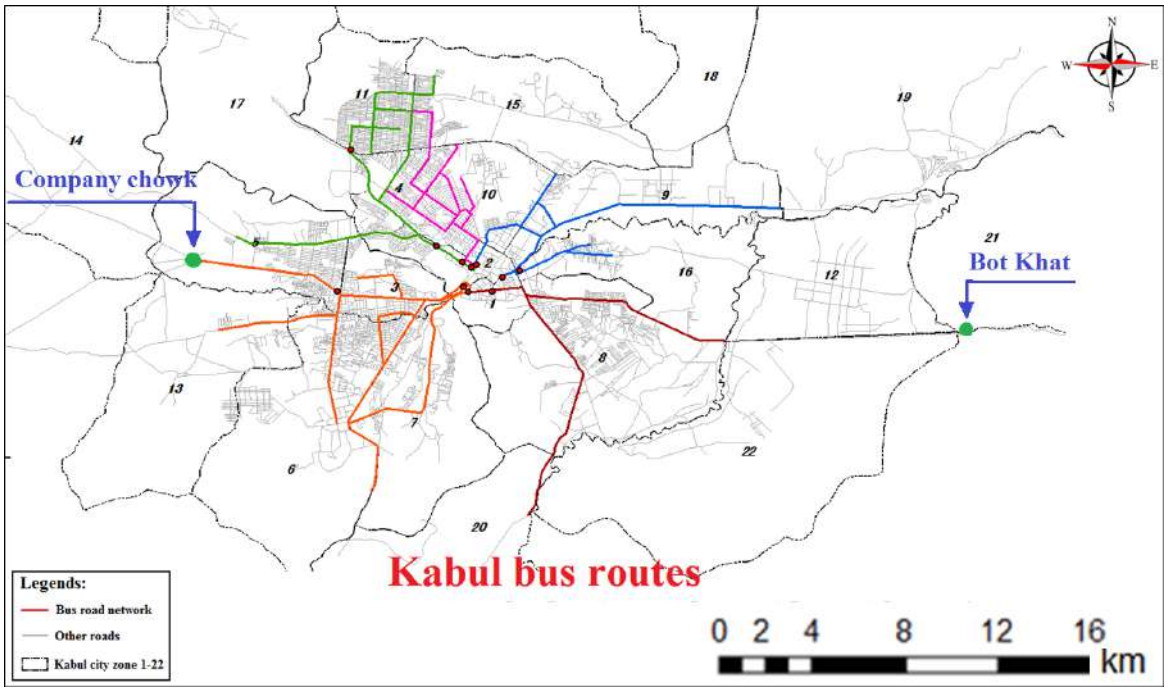


Figure 1.10: Bus road network of Kabul city

Chapter 2

Literature Review

2.1 General

The condition of Kabul city especially the public transportation system was discussed with details in the introduction part. Among different modes of transport serving as public transport $(Microbus, Minibus, and Car)$ there is only one government owned mode of public transport $(Milliebus)$ in Kabul city which is not capable of demand satisfaction at all, neither quantitative nor qualitative. Transportation plays the key role in the urban mobility and economic growth of cities, and countries. So, cities with poor transport systems can never meet their prospects of economic growth, quality life for the residents, and systematic heath care. So, improvement of the transportation system is not waste but invest; by which both the urban mobility and economic growth are simultaneously met. From the urban life point of view, the public transport network needs to be improved which is still too poor for Kabul. Transportation system needs to be improved, but the question arises here is how to improve it which could meet the demand satisfaction while following the national strategies $(e.g. Green Urban Transport Strategy)$. From another hand, Kabul is a morphologically polycentric city with the rapid increase in population which is desired to be transformed to a multiple-core form $(JICA, 2009)$. To achieve this transformation, the public transportation system needs to be adapted to this fact. At this stage, we need to study the monocentrism and polycentrism concepts and models in some other countries around the globe.

As per efficiency of source allocating point of view, the model of mono-centricity mostly depends on the central city portal function, while the over concentrated public service function‘s mono-centricity model weakens the competitiveness of secondary-size cities. The urban system of the polycentric network had open connection internally as well as externally which lead to furthest enhancement of the urban network externality avoiding the limitations of the city size to some extent; also can effectively achieve the urban function complementary in polycentric and networked mode $(Miaoxia, Z.etal., 2011)$ A city with the morphologically polycentric structure having monocentric transportation network planning cannot satisfy the user demand with desired comfort level as well as the operator cost, because of causing maximum PJT, delay, congestion, and high fare. For such cities the

concept of functional polycentrism comes into mind, it is nothing but transformation of the transportation network from monocentric to the polycentric structure also integrating the existing modes of transport. Here is the public transportation network plays the key role by connecting the urban-cores to each other as well as to the city center.

An attempt was made for integration of the public transport network using $VISUMmacrosimulationsoftware$ by $(Solecka, K.andZak, J., 2014)$. He stated the methodology of applying the $VISUM$ and carried out the comparison between two alternatives to know which one to be considered as less or more integrated. Public transportation assignment is consisting of the $threetypes$ of procedures say $Scheduled - based(SB), Headway - based(HB), andtransportationsystem - based(TSB)assignment$, among which the $(SB)and(HB)assignmentprocedures$ are more practiced in real life depending on the frequency of the line. To know in which condition either the $(SB)or(HB)$ have to be applied, findings of $(Cascetta, E.etal., 2016)$ shows that for lines with higher frequencies the $(HB)assignment$ behaves better, while for $lowerfrequencies$ the $(SB)assignment$ is $better$.

Today Kabul's morphologically polycentric structure with unimproved and monocentric transport network is too harmful to the people as well as the operators both from the economical aspect due to using private transport and the environmental aspects due to emissions. So, it is more interesting to make attempts for configuration of the public transport system $(PuTS)$ in Kabul city from monocentric planning to polycentric planning for immediate need satisfaction as well as future. So, in the following section, we will briefly discuss the concepts and models of monocentrism and polycentrism.

2.2 Monocentrism and Polycentrism

The background, models, and concepts of monocentrism and polycentrism are going to be discussed here. It is most essential to know these concepts, which will help us to understand the present, and future condition of Kabul city, accordingly to plan for future which could meet the future demand satisfied in modern and accepted manner.

2.2.1

The city which has a dominant urban-core is referred as a monocentric city. This core is mainly concentrating the main activities, shopping centers, entertainment and many workplaces. From another hand, the residents are willing to live in the suburbs; whereas lots of workplaces are in the inner city. So, it causes the city center to concentrate more commuting flows into itself which are made by residents.

Monocentric city models

For the first time $(VonThunen, 1863)$ developed the monocentric city model from his approximation. He stated the relation between farmland values and accessibility. Later, $(Alonso, W., 1964), (Muth, 1967), and (Mills, 1967; 1972)$ improved it. This monocentric model due to its simplicity, exactitude, and capacity to be contrasted empirically has been a very useful instrument. One of its bigger achievements has been to explain the residential decentralization process that occurred in most of the urban systems since the beginning of 21st century. Also, it can explain the economic organization of the cities.

The basic monocentric city model

Consider the most common monocentric model, in which the central business district (CBD) concentrates all production to itself, where the workers reside in housing that surrounds the . Housing Production takes place according to production function shown in below expression:

$$X_1 = f(L, K) \qquad (2.1)$$

Where,

$X1$: housing

L: land and,

K: capital

The objectives of the first models were to analyze the residential location. The main assumption of these models was such that all the workplaces were in the inner city and the families would compete for the houses with better access to the inner city. It appears in the bid-rent theory which explains how the land price increases with the decrease of distance from the center of CBD. The bid-rent theory is based on the fact that the more profitable areas are, the more accessible. This theory distinguishes some zones depending on the closeness to the inner city. These zones are shopping zone in the city center, followed by the commercial and office zone, and further the residential area respectively. It can be seen from the Figure 2.1.

Figure 2.1: Bid-rent theory

When people live far away from the city center, transportation costs increase. Therefore, the prices offered for the houses are lower to compensate this fact. There is an equilibrium point where land prices offset the lower costs of transports of houses close to the inner city. The differences in the price of the land of the inner city and suburbs explain the high-rise apartments in central locations and the garden apartments and townhouses in the places further from the inner city.

Evolution of a monocentric city

$The following steps briefly state the evolution process of the monocentric city$:

(a) They usually emerge from a square, which concentrates most of the important political and religious authorities living around it.

(b) Some villages become neighborhoods, the growth of the city is acquired as the streets get extended.

(c) Finally, it appears the shopping areas.

2.2.2 Polycentric city

The origins of the polycentrism

The monocentric city model with the assumption of a single employment concentration has been criticized on the ground that the cities it explains are from a different era. Because, as they growth in size, the original monocentric structure which has reached its large

metropolises also tends to dissolve into a polycentric structure accordingly progressively. The CBD tends to lose its primacy with time, while the activity clusters which generate trips are spreading within the built-up area. None of the large cities are born polycentric; they may evolve in that direction. Polycentric and monocentric cities are animals from the same species observed at a different time during their evolutionary process $(Bertaud, A., 2004)$. From Figure 2.2 the differences between monocentric and polycentric models can be easily seen. Monocentric models cannot explain the organization and configuration of the big cities. They cannot explain the location of the centers where people are willing to pay higher rents than in other areas closer to the city center.

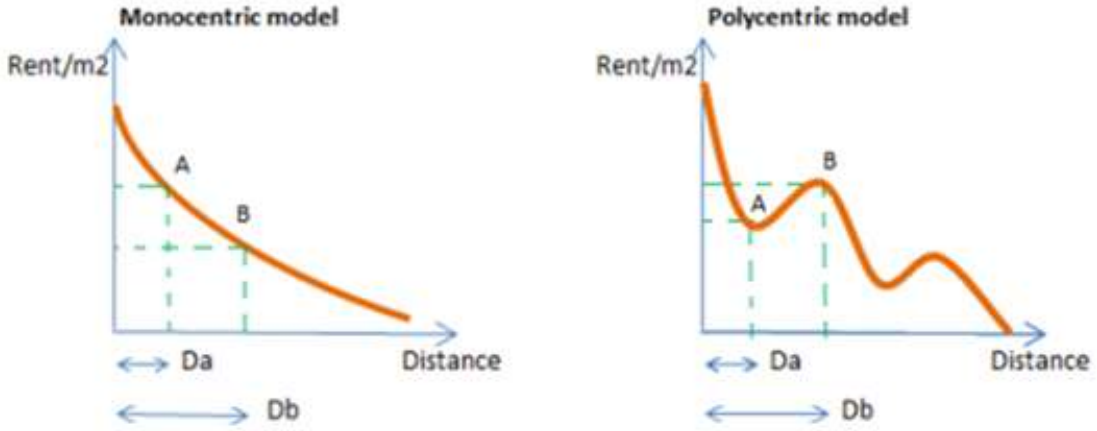


Figure 2.2: Rent levels at different distances from the city center in a monocentric and polycentric model

The reason why a polycentric city gets emerged is the presence of forces of agglomeration and dispersion. Also, changes in the climate, demography and the globalization impact challenges how societies evolve. For the first time $(Bertaud, A., 2004)$ argued that in the late 20th century there was employment dispersion. The percentage of works over time in the inner city decreased, and the new companies were located outside the CBD of cities. Later $(Romein, A., 2005)$ examined the structure diverging of many cities from the monocentric structure and randomly expansion of the daily trips over a wade were outside the inner city. In some cities, the development of expensive regional centers has made that the population there sometimes exceeds those of their center. The findings of the $(Organization for Economic Co-operation and Development, 2007)$ shows that the Ploycentricity refers both to the morphology of urban areas; structured around several urban nodes, and to the existence of functional relationships in terms of commuting flows between the cities and the centers of such regions, business and industrial relationships, forms of cooperation and the division of labour.

Polycentric city models

A theoretical framework developed by $(Fujita, M.etal., 2001)$ describes the polycentric structure evolution that been resulted from the centripetal forces and agglomeration of the economic relationship between firms. Thus, urban polycentrism is a spontaneous process of organizing economic activities in limited areas, with increasing population and investment capital in space, whose distribution allows reproducing the process. There are changes in the density pattern of the city as illustrated in Figure.2.3.

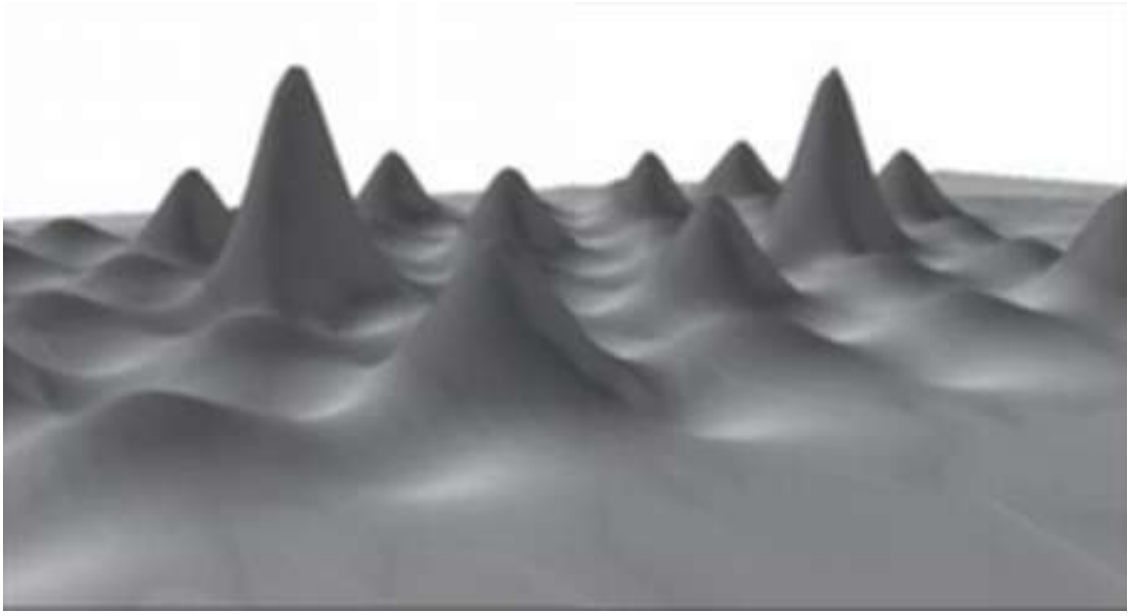


Figure 2.3: Structure of a polycentric city

The structure and the functionality are two different aspects. A city can be morphologically polycentric but not to work as a polycentric city. It can be seen from the Figure 2.4. The relation between the outer and the main core is what makes a city to have a polycentric behavior or not. Therefore, the transportation system plays an important role in this fact. A city that wants to be functionally polycentric should have and attractive transport system that makes easy to travel between all the cores to increase the relationships between them.

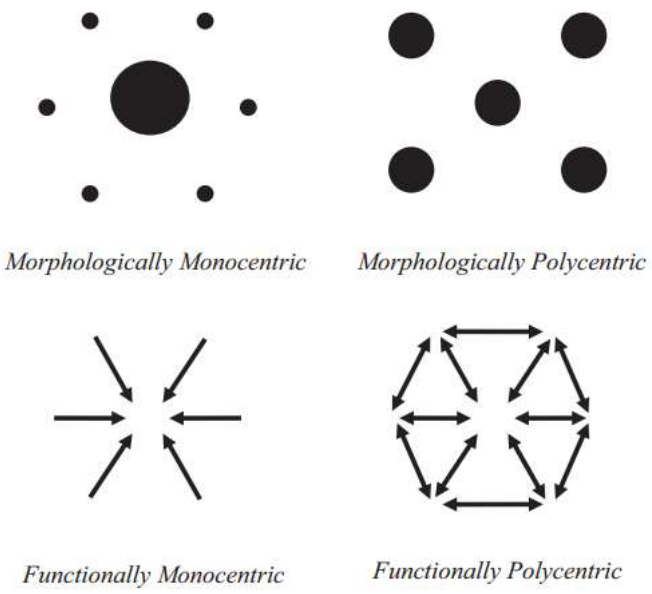


Figure 2.4: Functional polycentrism versus morphological polycentrism

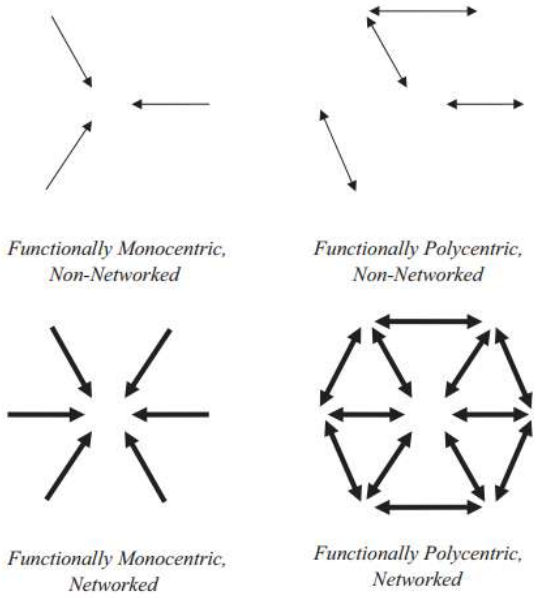


Figure 2.5: Functional mono/polycentric systems versus networked systems

2.3 Monocentrism and polycentrism in the cities around the world

Kabul is not only the city which has to be developed in either a monocentric or polycentric way. Both the structure and population distribution of a city have a direct relation to the way of the transport network planning. There are some cities in the world initially they had a polycentric structure and had adapted their transport network to this fact. Others that, due to the growth of population and its establishment in new areas, have been forced to

restructure the network to adjust it with the changings needs of the populations and others that are functionally monocentric as well. Hence, the following types of cities can be categorized:

- Cities with polycentric structures (with some external cores) with a transport system adapted to this fact
- Cities with polycentric structures (with some external cores) without a transport system adapted to this fact
- Cities that not have a lot of external cores and a more monocentric structure with a "polycentric" public transport node structure, and
- Cities that not have a lot of external cores and a more monocentric structure without a "polycentric" public transport node structure.

In the following sections, different cities around the world will be shown and classified as per the said concepts.

2.3.1 Lima City

Transformation of the Lima city from monocentric into a polycentric structure has been one of the most significant changes in its urban structure, argues $(Olarte, G.E.etal., 2012)$. The institutional changes, the accelerated process of capital accumulation and the demographic changes have been the main reasons for the appearance of the outer cores in Lima. Due to adjustment of the $(PuTS)$ to the new urban structure also the better residential location of the employees, significant reductions in travel costs, travel time, and initial waiting time have occurred.

Public transport in Lima City

Congestion caused by its public transport was the major problem of the Lima City. That is why they started many efforts for development of the systems such as the Metropolitan Transportation System, which aims to improve the quality and safety of the transport services in Lima.

- **Metropolitan transport system**

  Metropolitan Transport System is a Bus Rapid Transit System $(BRTS)$ along with proper integration with other available public transport modes in Lima. The length of this trunk line is $26km$ consisting of 28 stations; Figure 2.6 shows it. This system contributes the benefit for $700,000$ passengers.

- **Metro**

  Lima has an underground metro which runs through the city of Lima. It consists of the 26 passenger stations, with an average distance of 1.2 km from each other.

- **Bus**

  Lima, bus transport system, is compositely served by buses, microbuses, combis, as well as the "Sistema Integrado de Transporte Urbano" $(SIT - U)$, which is operating by Lima Council since 2014.

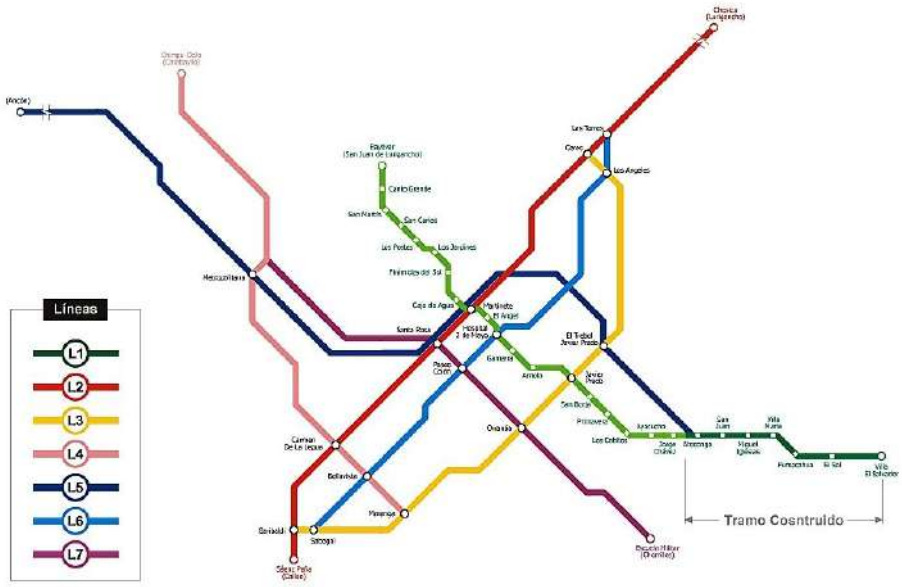


Figure 2.6: Lima network of the metropolitan transport system

Figure 2.7: Lima metro network

From Figure 2.7 it can be easily seen that there is no common point of confluence among all lines of the metro network. The polycentric structure of the transport system can be clearly seen as well; because there is no one of the cores more important than the

others. Integration is the most important aspect of public transport systems. That is why the Integrated Transport System in Lima $(SIT - U)$ exists. This transportation system is motivated by the Metropolitan Municipality of Lima and is in the process of implementation. The SIT objectives are the reduction of the current number of transport routes, renovation of the fleet of vehicles, and integration with rest of the transport services as the Metropolitan Transport System and the Metro.

Conclusions

A study to establish what the centers which organize the economic activity in the Lima have been done. After a theoretical review, to the case of Lima, a polycentric model was specified and checked empirically. The findings by $(Giuliano, G.andSmall, A.K., 1991)and(McDonald, J.F.etal., 1994)$ shows that a combination of methodologies was used that the employment centers have been identified by a combination of methodologies. The polycentric model has made it possible to analyze the economic density related with the distances and its effects in the location of economic activities. In the late 30 years $(Olarte, G.E.etal., 2012)$ token the statistical data about the gross density of employment. The urban structure of Lima has stopped being organized around a center and has formed a polycentric city with four centers consolidates and other in the course of consolidation. Because of the urban densification, the new centers have been emerging.

2.3.2 Moscow

Moscow is the city which is the second most populous city in the Europe, and the world's 18th largest city. The transport network is radial for Moscow as shown in Figure 2.8. The chief architect of the city $(Kuznetsov, 2012)$ argued, that was most important to make people aware that the periphery is not a place only to sleep. Also, it can be an area where they can have an exciting life. People's opportunities need to be expanded to spend more time in places close to their houses. $(Bertaud, A, 2001)$ said that currently employment in Moscow is strongly monocentric. It is due to its radial network of roads, also converging of all the metro lines toward the inner city.

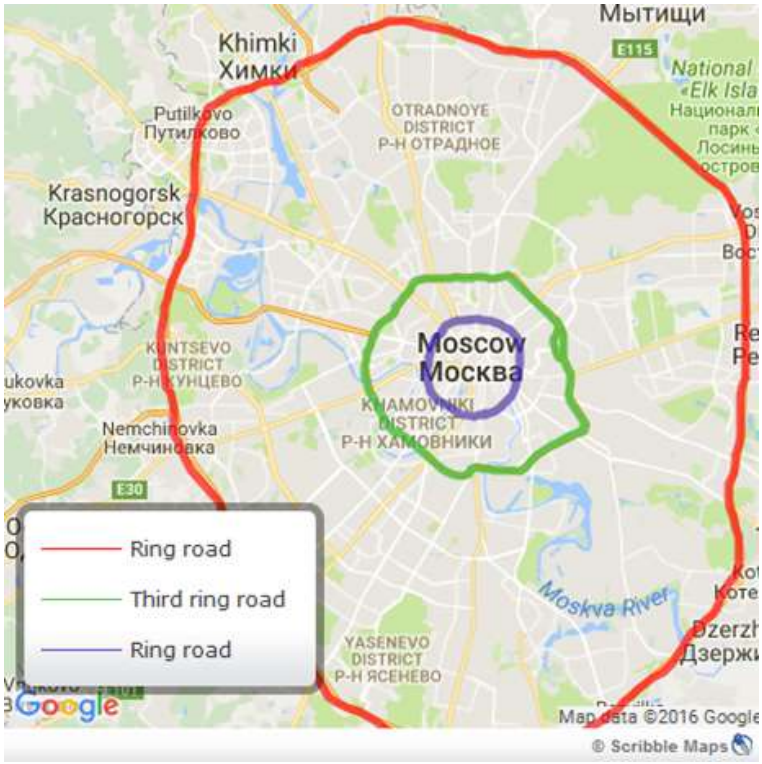


Figure 2.8: Arterial view of Moscow

Public transport in Moscow

Public transport in Moscow The city is served by a network which includes numerous trams, a monorail system, and a metro network.

- **Metro**

  The Moscow Metro had only two lines when it opened for the first time in 1935. Nowadays, it has 12 lines and 188 stations as shown in Figure 2.9.

- **Tram** Moscow tram line inaugurated in 1899. Its latest line was completed in 1984. Although nowadays the tram is used very low, still they serve as the metro feeders in some parts of the city and also provides cross-links between the metro lines.

Figure 2.9: Moscow metro network

2.3.3 Curitiba

Curitiba presented between the $(50's - 90's)$ one of the highest rates of annual growth compared to the other Brazilian capitals. The model adopted by the regulatory plan (1966), changed the radial conformation proposed by the previous plan for a linear model of urban expansion. Transport public, land use and integrated road system, they became used as instruments for the realization of that goal.

Curitiba is a city designed by an architect who was the mayor of the city as well. So, the necessity of being reelected tempered his design utopia. Curitiba is a monocentric city from employment aspect, but due to the recent construction of a ring road, an increase in job dispersion have occurred. As per $(Bertaud, A., 2001)$ the Curitiba zoning system was conceived by the planners as the design tool which would force the shape of the city into a predesigned mold. While, $(Alonso, 1964), (Muth, 1969), and (Mills, 1972)$ state that the resulted shape was such that to be deliberately different that of produced by the principle of the self-organization.

Figure 2.10: Integrated transport system in Curitiba

Public transport in Curitiba

Public transport network in Curitiba consists of the buses only. It is the opener of the world's first Bus Rapid Transit System $(BRTS)$.

- **Integrated transport network**

  It is a $BRTS$ implemented in 1974. The fleet of Integrated Transport Network amounts to 2160 buses of various types. It has 72 km of exclusive lines for buses. The stations are easily identifiable by a tube. Curitiba is, therefore, a city with morphological radial structure but a polycentric structure of the public transport network.

2.3.4 Barcelona

The Metropolitan Region of Barcelona (RMB) as a polycentric urban area has repeatedly been characterized $(Font, 1999)$. Administratively, Barcelona consists of ten districts. Each

district functions as an entity politician competencies, which is helpful to decentralize city politics. The city growth still follows the expansion plan designed by $(Cerda, I.1960)$, with the now famous orthogonal grid with chamfered crosses.

Barcelona's Public transport

A comprehensive local public transport network is serving Barcelona. The network is consisting of one metro network, two separated modern tram networks, one bus network, one separate historic tram line, and many funiculars and aerial cable cars.

- **Buses**

  Buses contribute as the major form of the Barcelona's public transport. They bus network is consisting of the extensive local, night, and interurban bus networks with a total of 150 circulating lines.

- **Metro and Trams**

  This metro consisting of the 11 lines with a total length of 123.5 km, is the Spain second largest metro after Madrid, while it is the first metropolitan railway network of Spain since 2009 which operates with fully automated lines. Barcelona is a polycentric city with an adapted public transport network. The public transport network has planned in a homogeneous and logical way to get a rational, comfortable, affordable and sustainable system that contributes to the improvement of the life quality also to respect the natural environment.

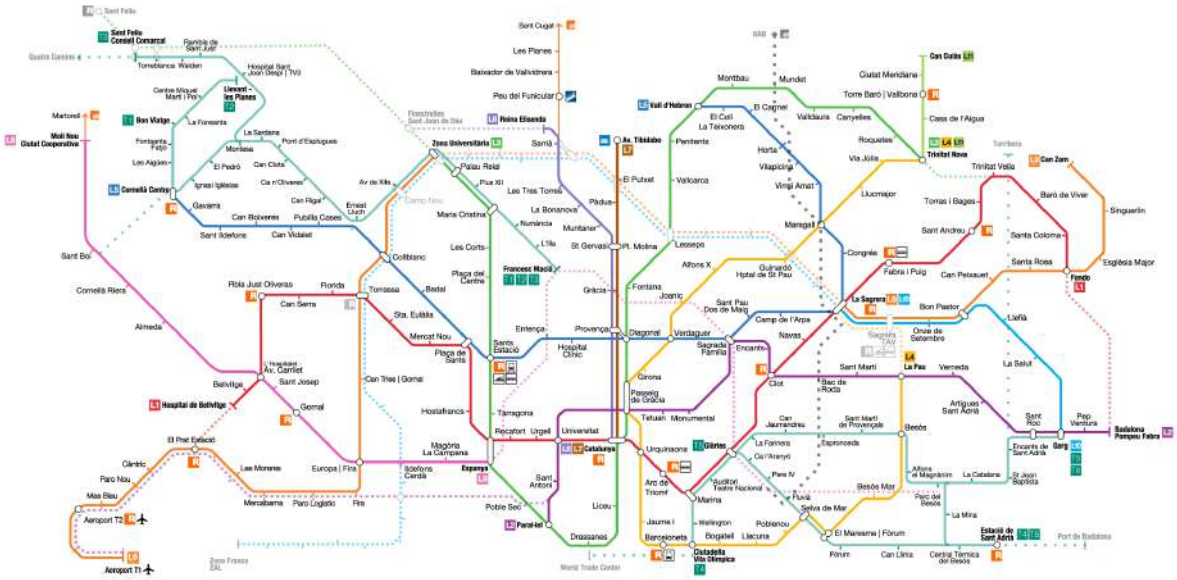


Figure 2.11: Barcelona metro network

Figure 2.12: Barcelona bus network

2.3.5 Madrid

Madrid metropolitan area is the 39^th biggest in the world and the $third$ in Europe after London and Paris. According to the modern concept of metropolitan area, there are some regions classified with different intensity in their urban relations as followings:

- Metropolitan urban area
- metropolitan suburban, and
- expansion area

Madrid's Public transport

Madrid public transport consists the metro 13 lines, bus lines more than 170, and Cercanias 10 lines (local trains which serve to link the city center to suburbs).

- **Metro**

  Madrid Metro is one of the fastest growing, and most extensive metro networks of the world. Currently, it runs over around 283 km comprising 13 lines with 238 stations.

- **Buses**

  Buses are extensively supporting the metro network by providing feeder services. The network fleet size is more than 2000 vehicles operating on 194 lines. From the Figure

2.13, lots of rings in the Madrid metro network can be seen, especially a satellite ring in the south (green color on the map). It is called MetroSur. It is a circular line of the Madrid Metro. The ring is not Madrid City but serves to link the five suburban towns in southern part of Madrid. MetroSur with a total length is $41km$ consisting of 28 stations, serves around 1 million persons in the southern part.

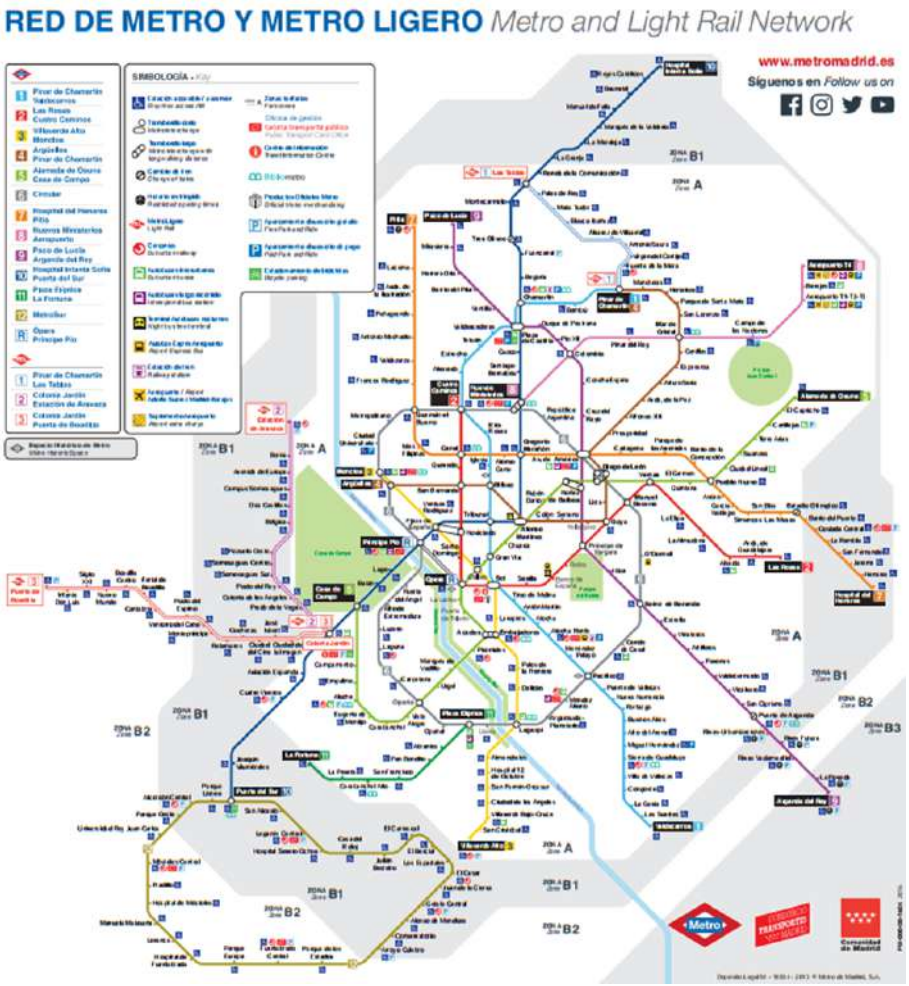


Figure 2.13: Madrid metro network

2.3.6 Detailed study of Madrid and Barcelona

Researchers from the Center of Land Policy and Valuations of the Polytechnic University of Catalonia (UPC), $(Roca, J.etal., 2011)$ conducted a study in this regard. They developed a methodology to simultaneously define metropolitan areas, identify metropolitan subsystems articulated around the sub-centers and test the hypothesis that the polycentric city is more efficient than the monocentric city from the environmental perspective of land consumption. The study made a comparison between Barcelona and Madrid, the two most important and main cities in Spain.

The study found that by applying the classical approaches to the analysis and detection

of the polarities of employment, Madrid and Barcelona have approximately equal number of sub centers identified, which is not consistent with local knowledge, which Madrid recognizes a high degree of monocentrism, versus a more polycentric structure in Barcelona. A more careful analysis allows concluding that the similarity revealed by classical approaches between the two metropolitan areas concerning its polycentric structure is more apparent that real. Most of the candidates for sub-centers of the metropolitan system of Madrid show elements of weakness that allow doubting his real role of sub-centers; the aspect that does not occur in the case of Barcelona.

The paper suggests that finding some differences in the density pattern is not enough. It is also essential that these nodes represent real unifying elements of urban subsystems within the overall structure of the metropolis. A sub able to configure cities within the metropolitan city understood as a true city of cities.

Thus, the Madrid and Barcelona transportation system is "polycentric," but the structure of Barcelona is polycentric while it is monocentric for the case of Madrid.

2.4 Kabul city

In this section, the structure of transport network of the Kabul city with the introduction of the important urban-cores will be briefly discussed.

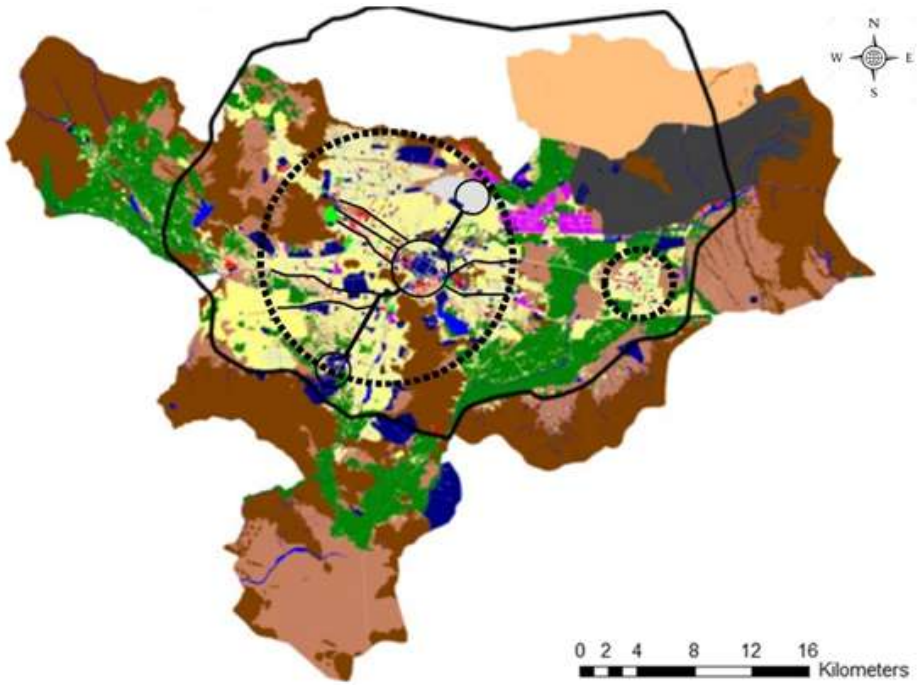


Figure 2.14: Urban structure of the Kabul City

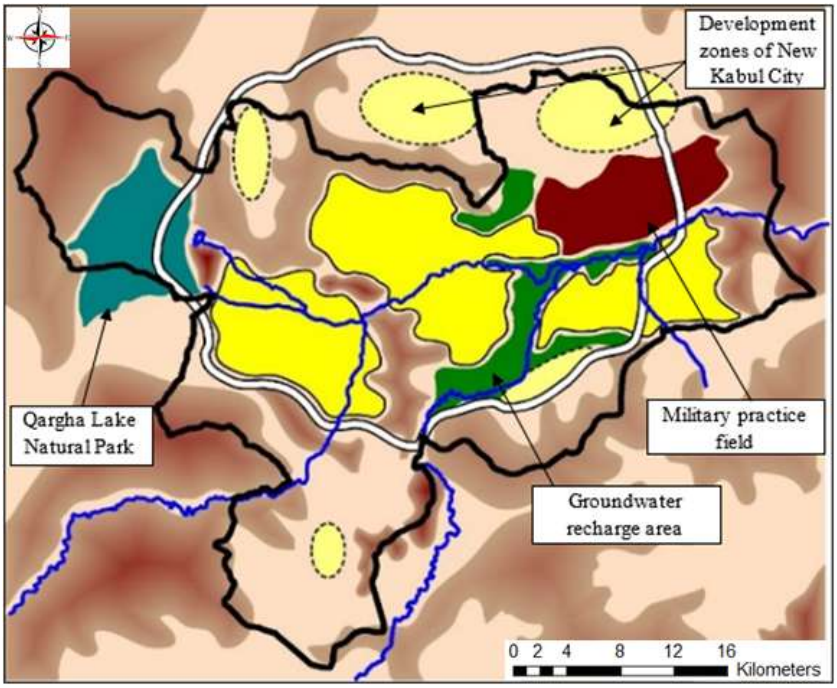


Figure 2.15: Composition of the Kabul City future urban areas

2.4.1 Kabul public transport scenario

As people in Kabul suffer from the weak public transport system; so in the revised master plan of Kabul city (2011), the concept of polycentric transport network has been mentioned. As per the master plan, some ring road of about 105 km is planned which will connect the urban cores to each other (to prevent congestion in the inner city). This ring road is mainly planned to reduce the external-external trips which are now crossing the city center, and connectivity among the urban-cores. As stated in the chapter1, the public transport condition is too harmful to the residents. The question arise here is, what will be the immediate/midterm solution for improvement of public transport, and how to optimally utilize the opportunities by which to satisfy the demand for today and tomorrow in a sustainable manner?

In this study, the line which is supposed to be proposed will be the integrated one with the current public transport network of Kabul. It will be the line from Company chowk to Bot Khak. Currently, no direct public transport service is available on the said route. The people who want to travel along this route have to use minimum four line routes $(CompanyChowk - Mirwaismaidan - MaiwandChowk - BotKhakChowk - BotKhak)$. As bus cannot serve all the four mentioned routes, so people depending on the importance of their travel have to pay fare from $5 to 20 Afghani$ for Millie bus and taxi respectively.

Public transport

As stated earlier, the government-owned mode of public transport of Kabul City is only the large bus mode. It is operated by the Millie bus authority which was established 1979 with primary 1500 buses for all the country. Unfortunately, now it has only 80 buses which are too less compared to the demand. It means that due to less attention to the Millie bus authority, finally it stopped the subsidiary services since 2010; and most of the public transport of the city is operated by the private sector. Nowadays even taxis serve as public transport mode with fare rate of two to four time that of Large bus and microbus respectively, which is harmful to the environment and the main reason for congestion.

- **Bus lines**

  There are total 54 line routes with the total length of $473km$, the average trip of 8.8 per route, and ten desired bus stops. They are mainly operated by the private agencies with around 14000 microbuses, 25000 Minibuses, 500 large buses (private), and taxis. Most of the suburbs are served by Microbuses and taxis, while the large buses mainly serve the inner city.

2.5 Conclusions

Kabul is the morphologically polycentric city, the travels by car will increase due to providing more speed and better accessibility for the people traveling from north to south, east to west, and other urban-cores of Kabul; because they want to reach their jobs in time, which is not possible with buses. In such case for reduction of trips by cars, the public transport network should be such that to attract the people.

Although polycentrism requires more land and dispersion of people in the urban-cores which causes more pollution but using more number of cars are also a huge challenge to the environment. Hence, strong transport network which could change the habit of people from using cars to the use of public transport public transport will be more helpful to the emission reduction. While the fare reduces four times that of taxis, and public transport with direct routes will be maintained instead of taking up to four routes from the origin (Company Chowk) to the destination (Bot Khak).

Chapter 3

Study Area and Data Collection

3.1 Study Area

Afghanistan is a country in the central part of the Eurasian Continent between the latitudes of $29^0 - 30'$ and $38^0 - 31'$ north and longitudes of $60^0 - 30'$ and $72^0 - 00'$ east with the surface area of above $655,000\ km^2$, in which Kabul city has a total area of $1022.7 km^2$ (JICA, 2009). As the transportation corridor in Afghanistan provides the shortest route to the sea ports, which is the main reason why Afghanistan is the country with strategic importance for Central Asian countries also Russian Federation.

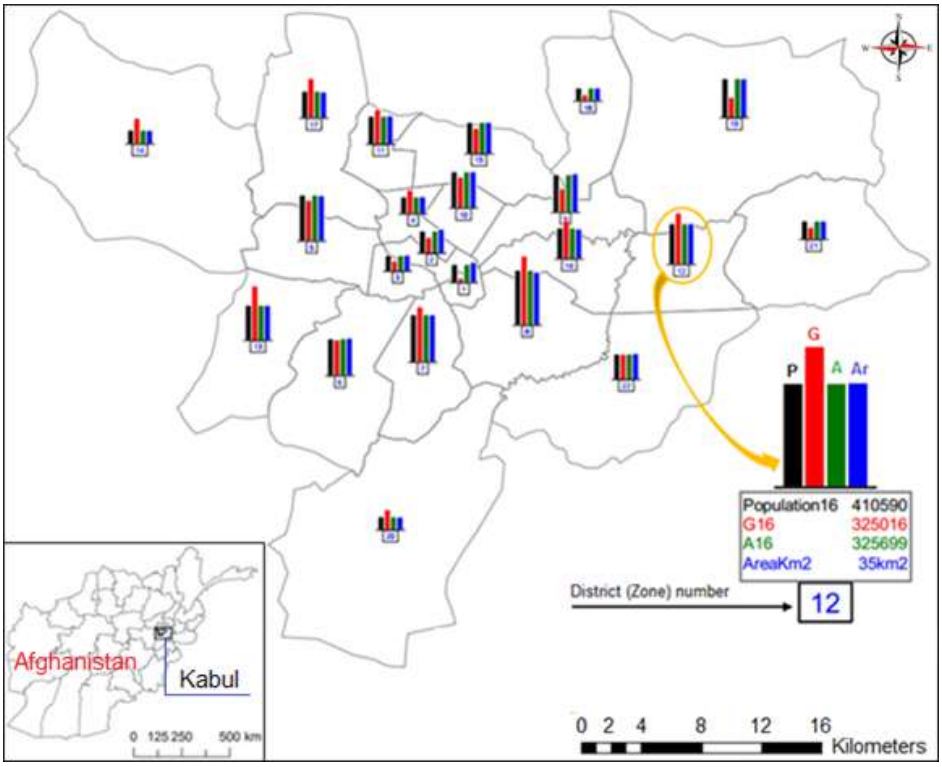


Figure 3.1: Current territory, socio-economic parameters, and location of Kabul old city

The study area is the capital city of Afghanistan which is located in north-eastern part of the country, with the elevation of flat area $1780 - 2000$ meters above mean sea level in lower and upper Kabul basin shown in Figure 3.1. The northern and south adjacent areas of

the city are largely consisting of the basins cluster with relatively flat land with the mountain ridges surrounding.

Presently the Asmai mountain ridges and Kabul River have divided the Kabul city is into the two northeastern and southwestern parts. Over the millennia, the city due to following main two reasons has been supported among others:

1) Its geographic location as the cross point of the North-South and East-West transit routes of Afghanistan.

2) The upper Kabul basin water resources.

Figure 3.2: Geographic view of Kabul city, traffic congestion, and heterogeneity

3.2 Zoning System of the Study Area

Typically for each traffic demand survey, the study area has to be determined and divided into some small zones based on land use pattern. Then cordon line (to determine external trips) and screen line points to be determined. Here the study area was divided into 78 small internal zones (Kabul old and new cities), and eight external zones among which the zone $27-30$ are belong to the outside north, south, east, and west of Kabul; and rest of the zones 31-34 are belong to outside of Afghanistan (including Kabul airport) as shown in Figure 3.3. Later the internal zones were converted into 26 main zones (districts), where zone 1-22 are belong to Kabul old city, and rest of them $23-26$ are belong to Kabul new city.

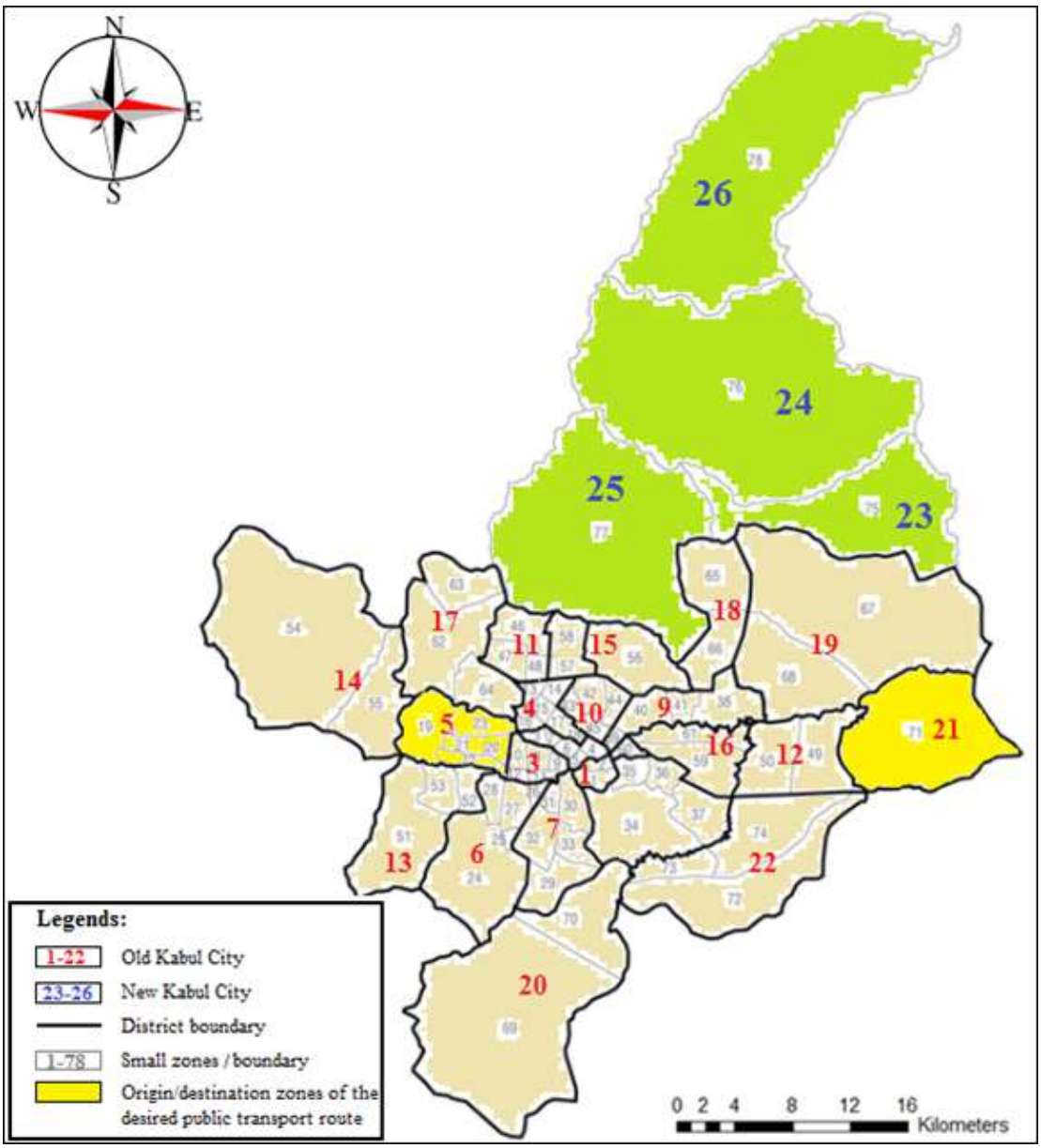


Figure 3.3: The study area zoning system

3.2.1 Data Collection

Require input data to be introduced for VISUM will be as follows:

- Demand matrix (O-D Matrix), and
- the network supply

Demand matrix as the output from the second step $(tripdistribution)$ of the traditional four-step demand modeling process, cannot be obtained directly from field observation. It needs some statistical data which has to be used in the trip distribution model. So, using VISUM on the basis of available parameters of the distribution model $(JICA, 2009)$ it was generated. Here, we gathered some primary and secondary data as following:

- Information about zoning system for demand data collection
- socio-economic statistical of the Kabul city
- traffic characteristics
- land use plans
- bus line routes map and,
- The network supply data were collected to evaluate the Public transport network of Kabul city becoming a multiple-core city.

Screen line and cordon line survey

In 2008 a study was conducted in Kabul city. As per the very beginning section of this chapter, the Asmai mountain ridges and Kabul River both as the main obstacles lead all the trips from northeast to southwest side and vice versa to use any one of the three arterials shown in Table 3.1. Based on this fact, the screen line survey crossing main roads was conducted; the survey points are shown in Figure 3.4. The cordon line survey was also conducted, and the cordon points of the study mentioned above are shown in Figure 3.5.

The data from the screen line and cordon line surveys were collected during $7amto6pm$ $(JICA, 2009)$. The network supply data was also mostly collected from 7 am to 7 pm. Summary of the collected data is shown in the following figures.

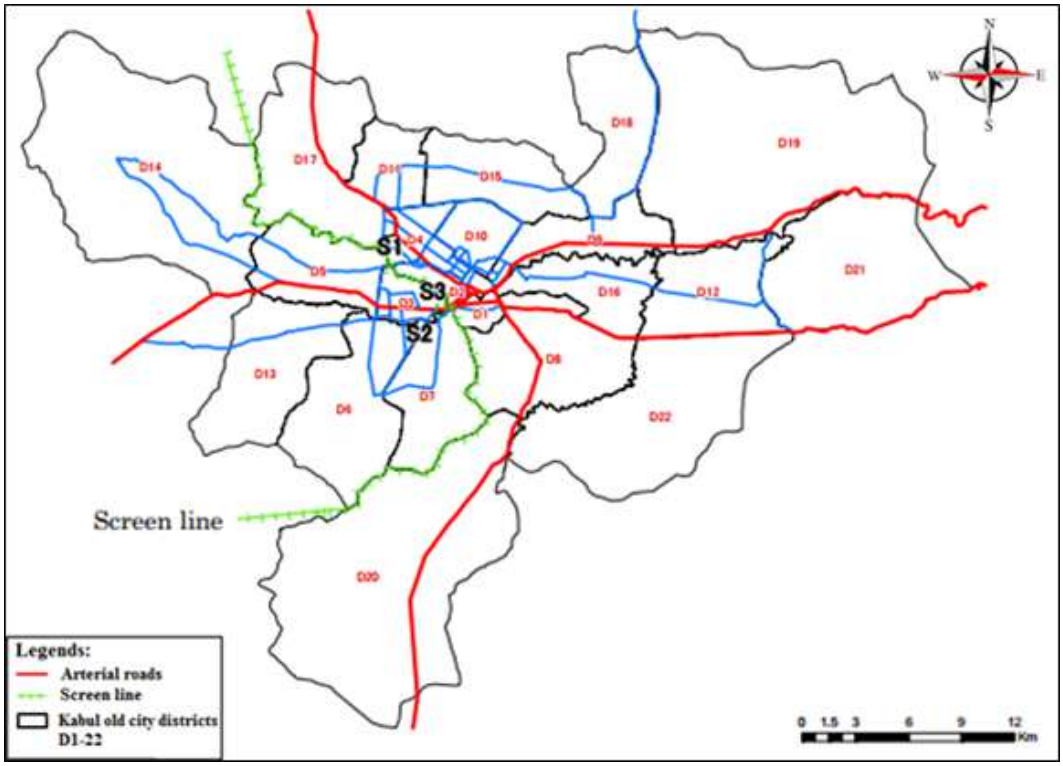


Figure 3.4: The screen line survey points in Kabul city

Table 3.1: Notations for the screen line survey

Point name	Description of the road
S1	Bagh Bala Road
S2	Jadayi Sehi Aqrab Road
S3	Guzarga Road

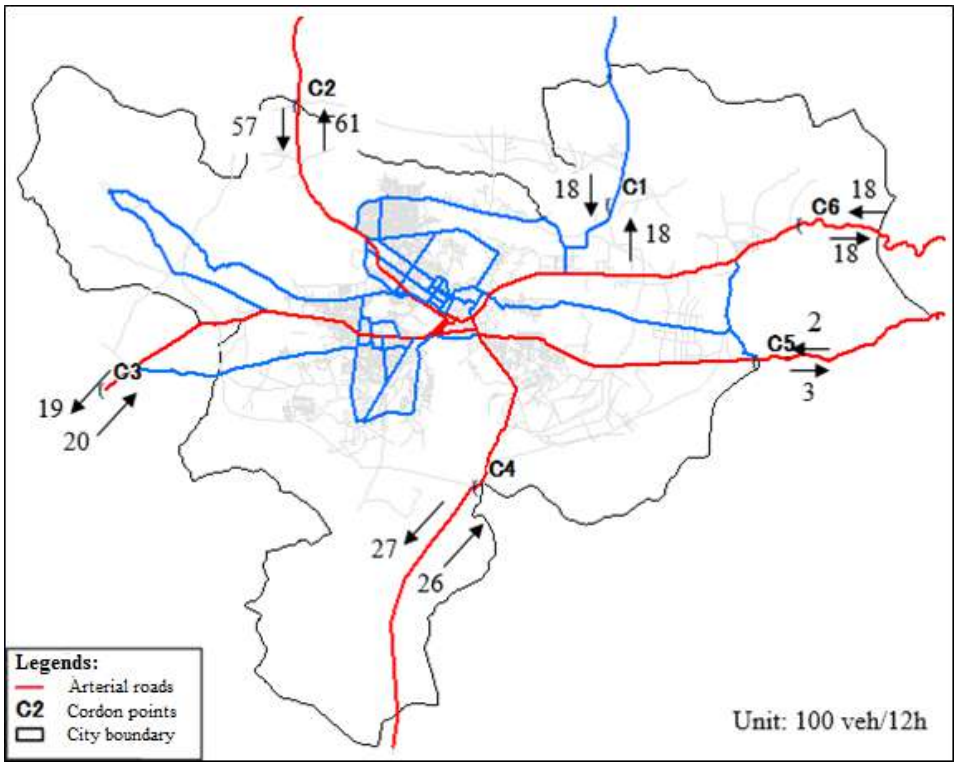


Figure 3.5: Points of the he cordon line survey in Kabul city

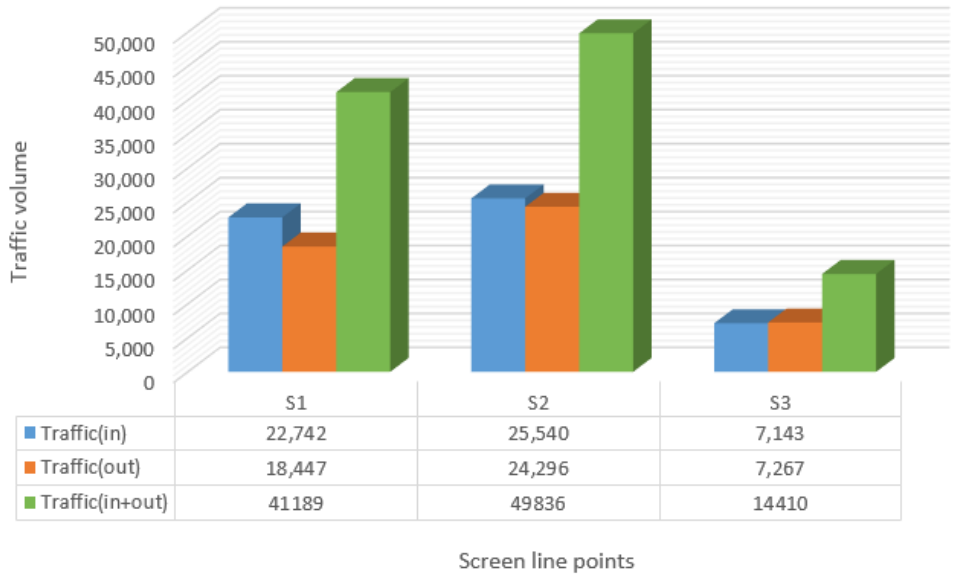


Figure 3.6: Traffic volume on the screen line

Table 3.2: Conversion factor to PCU

Vehicle type	Bike	Car	Taxi	Microbus	Minibus	Large Bus	Truck
Conversion factor	0.5	1	1	1	2	3	3

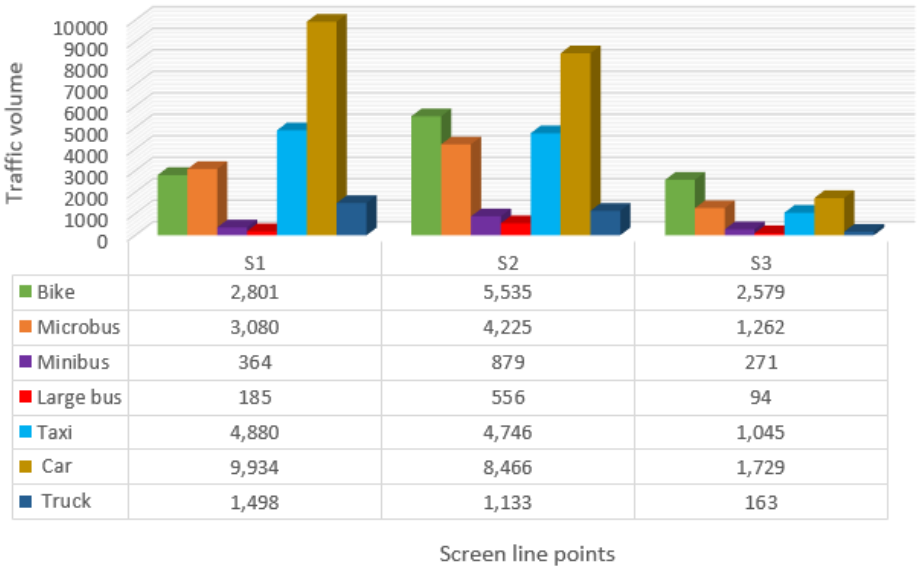


Figure 3.7: Traffic volume on the screen line by vehicle type (Inbound)

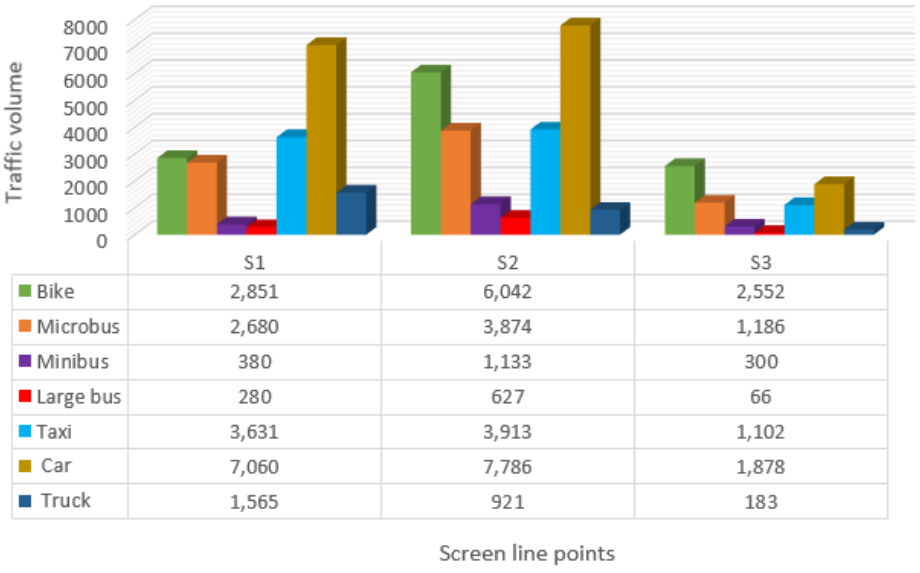


Figure 3.8: Traffic volume on the screen line by vehicle type (Outbound)

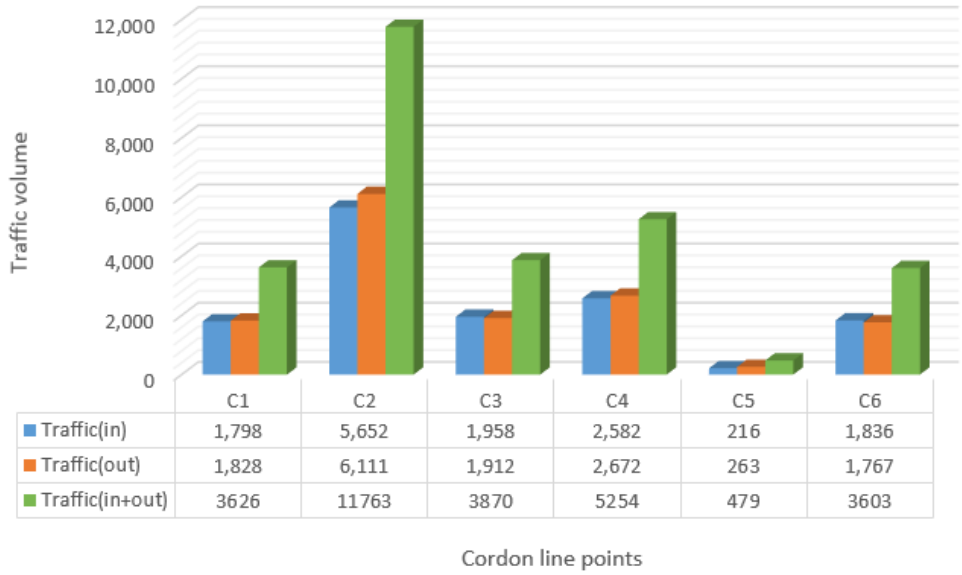


Figure 3.9: Traffic Volumes on Cordon Line

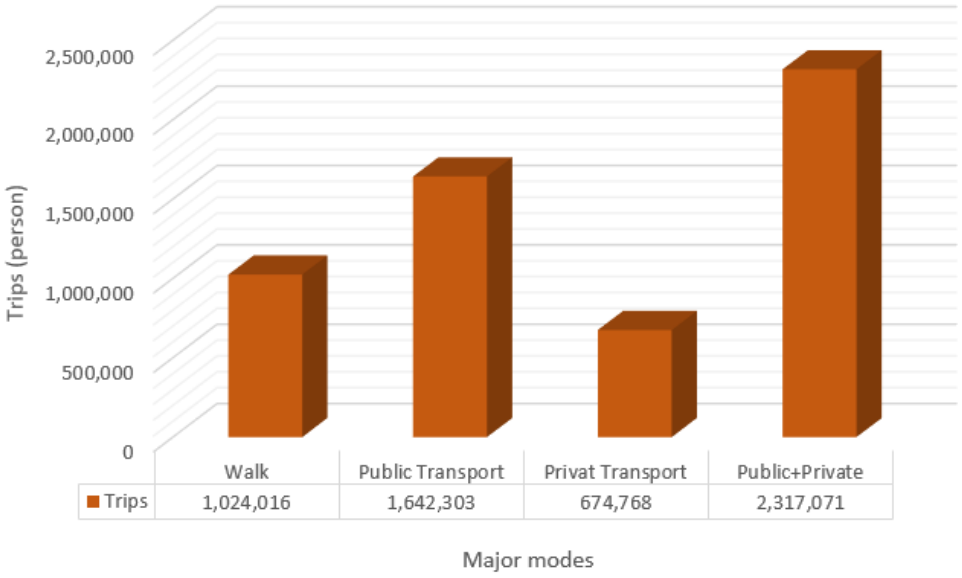


Figure 3.10: Kabul city related daily trips by major modes (including external-external trips)

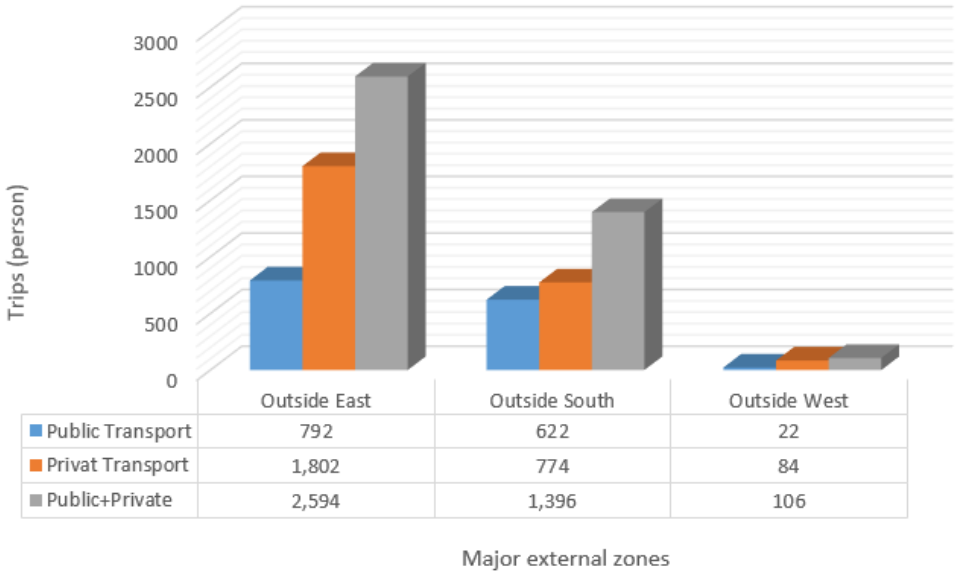


Figure 3.11: Kabul city related daily trips (only external trips)

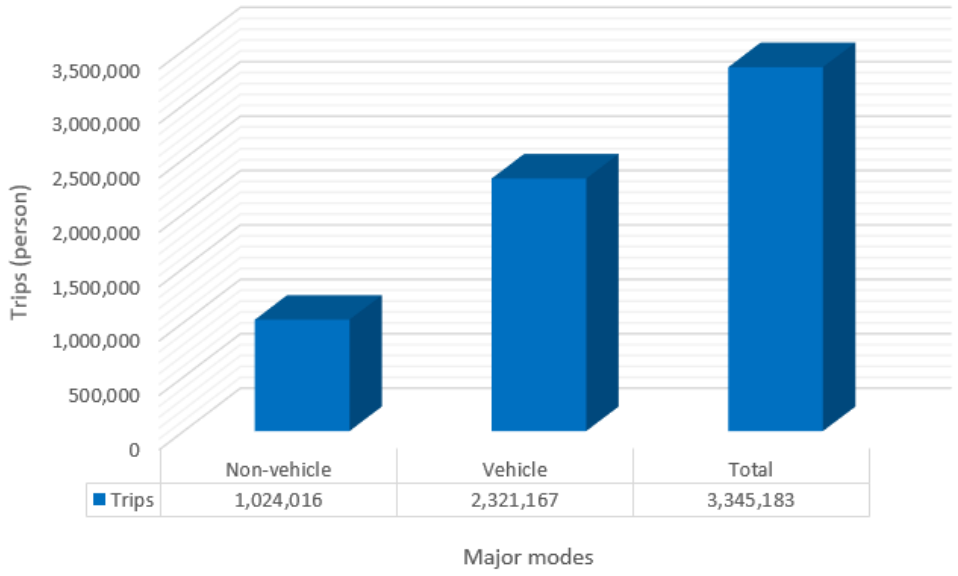


Figure 3.12: Kabul city related all daily trips (including external and airport trips)

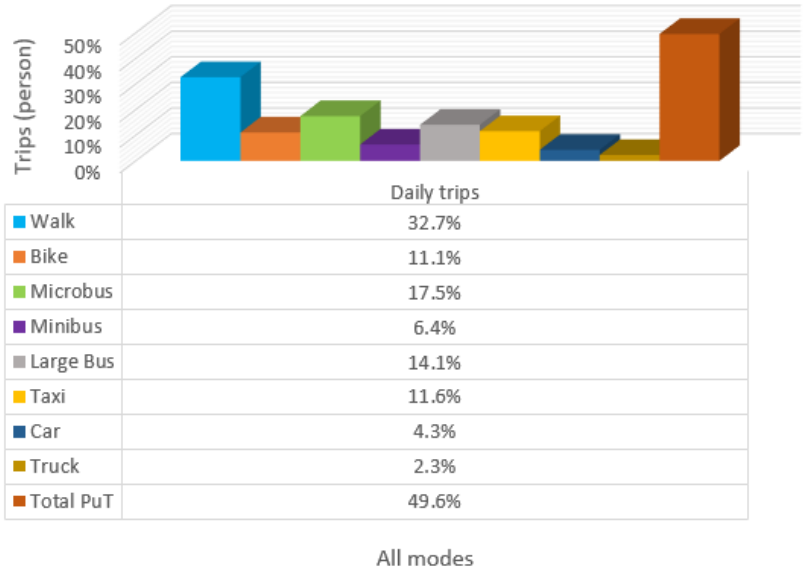


Figure 3.13: Kabul city related all daily trips by purpose (excluding external-external)

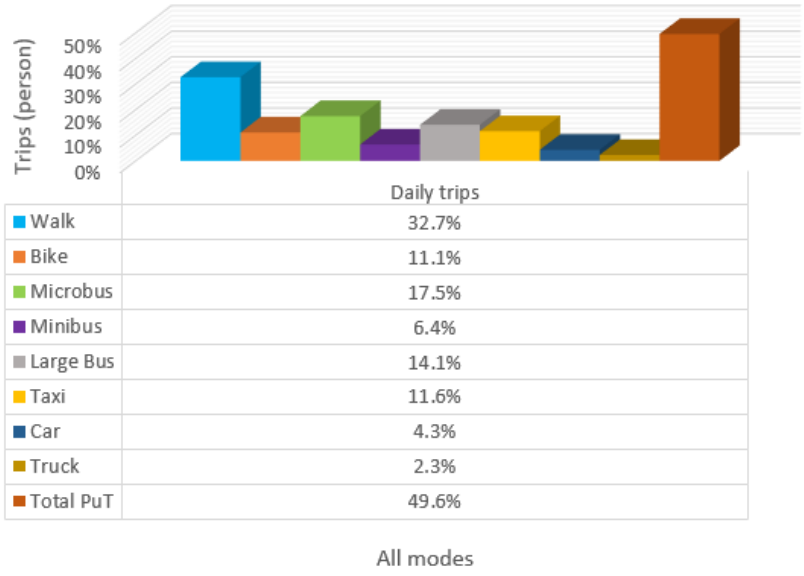
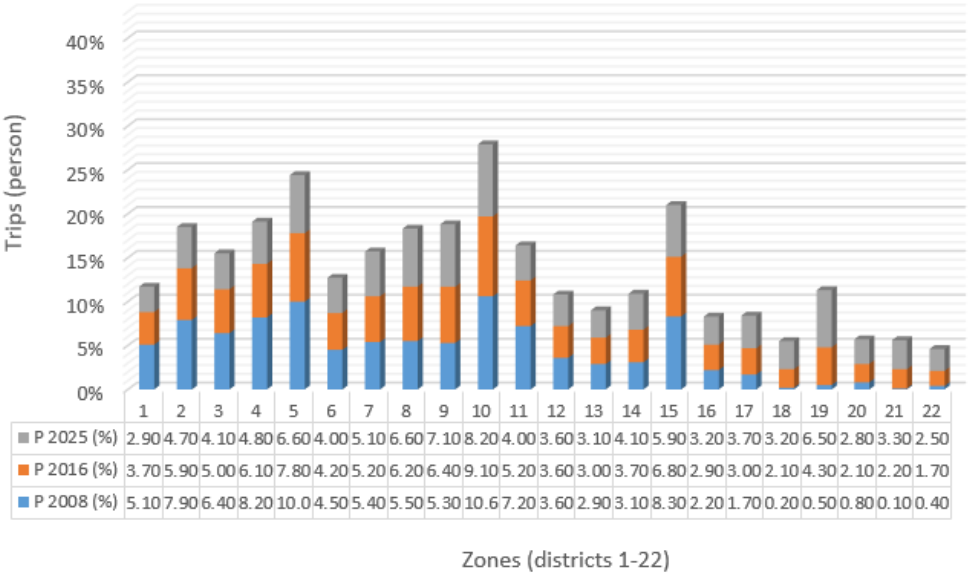
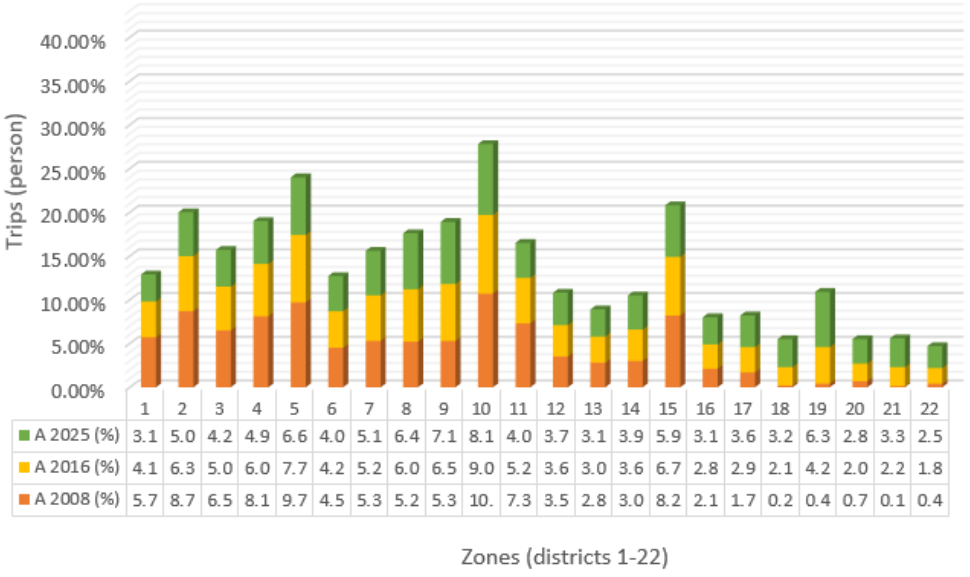


Figure 3.14: Share of different modes (excluding external-external)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
P 2025 (%)	2.90	4.70	4.10	4.80	6.60	4.00	5.10	6.60	7.10	8.20	4.00	3.60	3.10	4.10	5.90	3.20	3.70	3.20	6.50	2.80	3.30	2.50
P 2016 (%)	3.70	5.90	5.00	6.10	7.80	4.20	5.20	6.20	6.40	9.10	5.20	3.60	3.00	3.70	6.80	2.90	3.00	2.10	4.30	2.10	2.20	1.70
P 2008 (%)	5.10	7.90	6.40	8.20	10.0	4.50	5.40	5.50	5.30	10.6	7.20	3.60	2.90	3.10	8.30	2.20	1.70	0.20	0.50	0.80	0.10	0.40

Figure 3.15: Trip production by all purposes in each zone of Kabul city (zone 1-22)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A 2025 (%)	3.1	5.0	4.2	4.9	6.6	4.0	5.1	6.4	7.1	8.1	4.0	3.7	3.1	3.9	5.9	3.1	3.6	3.2	6.3	2.8	3.3	2.5
A 2016 (%)	4.1	6.3	5.0	6.0	7.7	4.2	5.2	6.0	6.5	9.0	5.2	3.6	3.0	3.6	6.7	2.8	2.9	2.1	4.2	2.0	2.2	1.8
A 2008 (%)	5.7	8.7	6.5	8.1	9.7	4.5	5.3	5.2	5.3	10.	7.3	3.5	2.8	3.0	8.2	2.1	1.7	0.2	0.4	0.7	0.1	0.4

Figure 3.16: Trip attraction by all purposes in each district of Kabul city (zone 1-22)

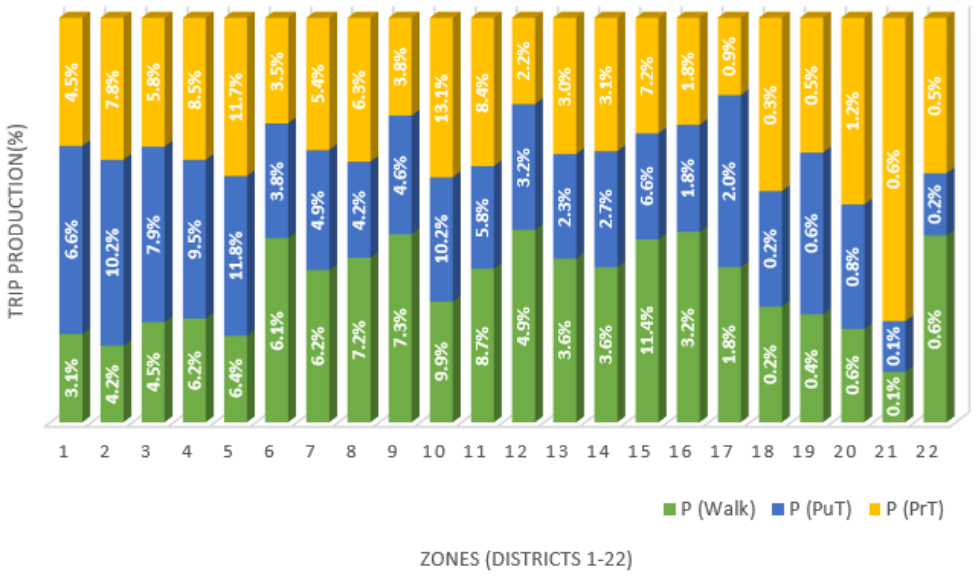


Figure 3.17: Trip production by transport mode in each zone of Kabul city (zone 1-22)

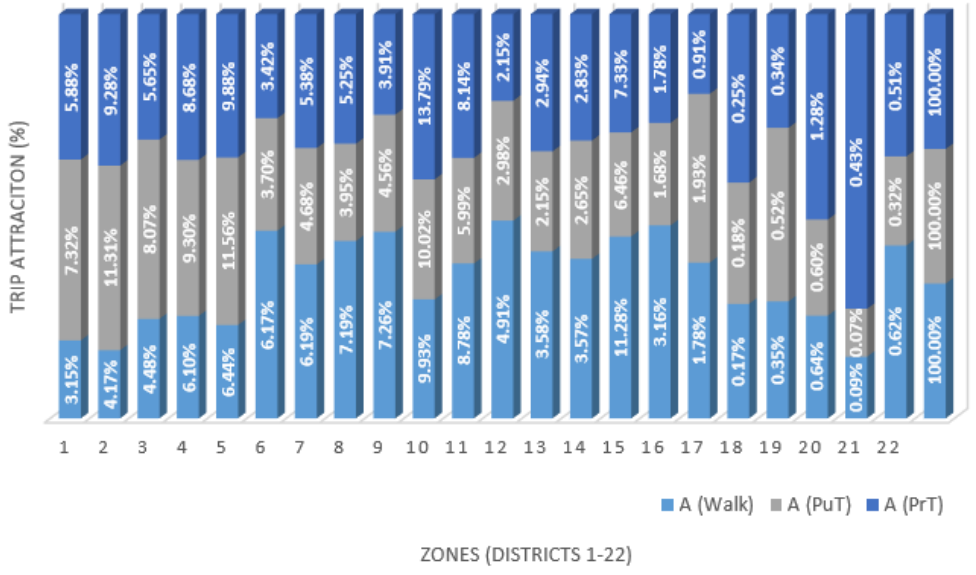


Figure 3.18: Trip attraction by transport mode in each district of Kabul city (zone 1-22)

Chapter 4

Methodology

4.1 General

The flowchart of the methodology followed here is shown in Figure 4.1. A detailed description of the methodology is given in the following sections.

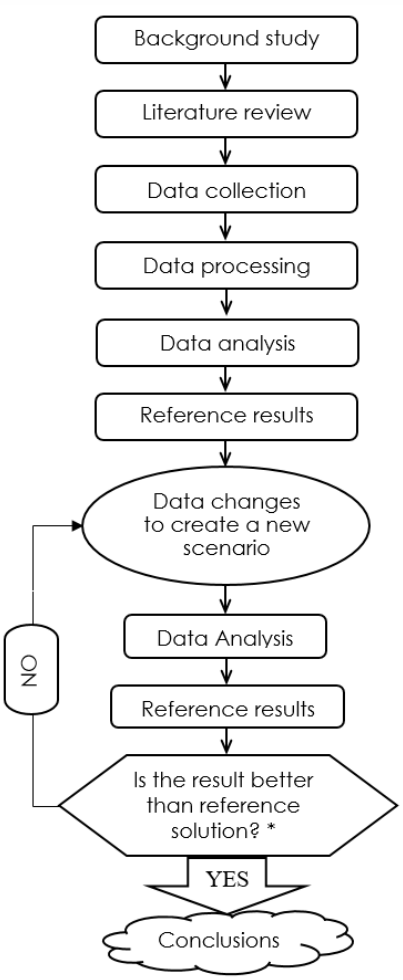


Figure 4.1: Methodology framework

Methodology framework used here is consisting of three major steps stated below:

a) Creation and modification of the transportation network, also defining alternatives

b) Applying the macro-simulation model of $VISUM$ to each alternative of the network

c) The comparative analysis and evaluation of the alternatives

There are three possible route :

- Transport system-based assignment
- timetable-based assignment and,
- headway-based assignment

The assignment procedure followed her is the .

4.2 Description of the methodology

The following sections will provide description about each particular step of the methodology.

4.2.1 Background study

This section consists of general information about the country and some discussions about the previous, current and future plans; and structure of the Kabul city given in the Chapter 1.

4.2.2 Literature Review

This section consists of the basic concepts of monocentrism and polycentrism, and study of Kabul and some other cities around the world from the functionality of the transport point of view, which is covered in Chapter 2.

4.2.3 Data collection

The scope of data collection is to know about the network supply and demand matrix. The supply side information as much as available was introduced to the network with the proper format. Demand O-D matrix refers to the base year 2008 (JICA, 2009), and predicted demand for 2016 and 2025. For more information about the study area and data collection, you may refer to Chapter 3.

4.2.4 Data processing

VISUM is the software used here. It is a Germany-based software for the travel demand modeling and the impact on private and public transport network. Once the data is collected and decoded; then for the creation of the public transport network (Zones, nodes, links, stop points, etc.) in VISUM, it is introduced as the attributes of the network.

4.2.5 Data analysis

After creation of the public transport network in $VISUM$, the means of transport and demand segments are properly introduced. Once all the network component with the relevant components are properly introduced and tested, the next step is to run the four-step demand models in $VISUM$. In order to run the four-step demand model in VISUM, it is essential to understand the data flow models and process in $VISUM$. Data flow is defined by using demand strata and demand segments. Among this, demand strata are to trip generation, distribution, and mode choice; demand segments, on the other hand are associated with route choice $(tripassignment)$. Figure 4.2 illustrates the four-step demand model process.

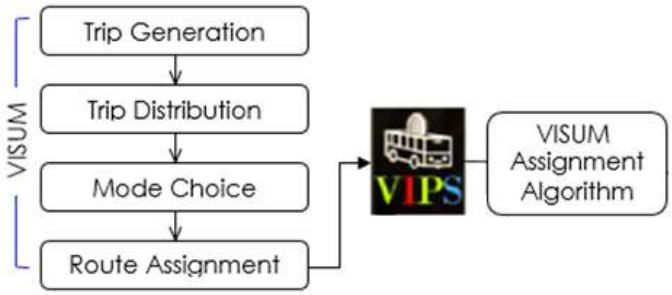


Figure 4.2: The four-step model procedure

Here, we are going to use the route assignment model of VISUM for which works with a static O-D matrix. Rest of the required information about the demand, modes of transport, and share of them are given in $Chapter3$. In order to run the public transport assignment procedures in $VISUM$, an impedance function has to be introduced, by which $VISUM$ will choose a particular connection from several indicators of this connection. The impedance consists of the time indicators and travel costs as shown below:

$$Impedance = F_1 \times PJT + F_2 \times Fare \qquad (4.1)$$

Where,

$$= w_{IVT} \times t_{IVT} + w_{AUX} \times t_{AUX} + w_{AT} \times t_{AT} + w_{ET} \times t_{ET} + w_{WT} \times t_{WT} + w_{OWT} \times t_{OWT} + w_{TWT} \times t_{TWT} + w_{NT} \times n_{TR} + BP_{PUT} + BP_{AUX} + P_{MD} \qquad (4.2)$$

VISUM calculates the headway-based assignment to minimize the expected travel time for all the demand.

Notations:

F_1 : Factor for PJT = 1.20

F_2 : Factor for fare = 1.10

w_{IVT} : weightage for in-vehicle time = 1.00

w_{AUX} : weightage for Put-Aux ride time = 1.00

w_{AT} : weightage for access time = 1.80

w_{ET} : weightage for egress time = 1.80

w_{WT} : weightage for walk time = 1.50

w_{OWT} : weightage for origin wait time = 1.80

w_{TWT} : weightage for transfer wait time = 1.80

w_{NT} : weightage for number of transfers = 5 min

t_{IVT} : in-vehicle time = (From simulation)

t_{AUX} : Put-Aux ride time = //

t_{AT} : access time = //

t_{ET} : egress time = //

t_{WT} : walk time = //

t_{OWT} : origin wait time = //

t_{TWT} : transfer wait time = //

n_{NT} : number of transfers = //

BP_{PUT} : boarding penalty for PuT = 0

BP_{AUX} : boarding penalty for PuT-Aux = 0

MD : mean delay = 0

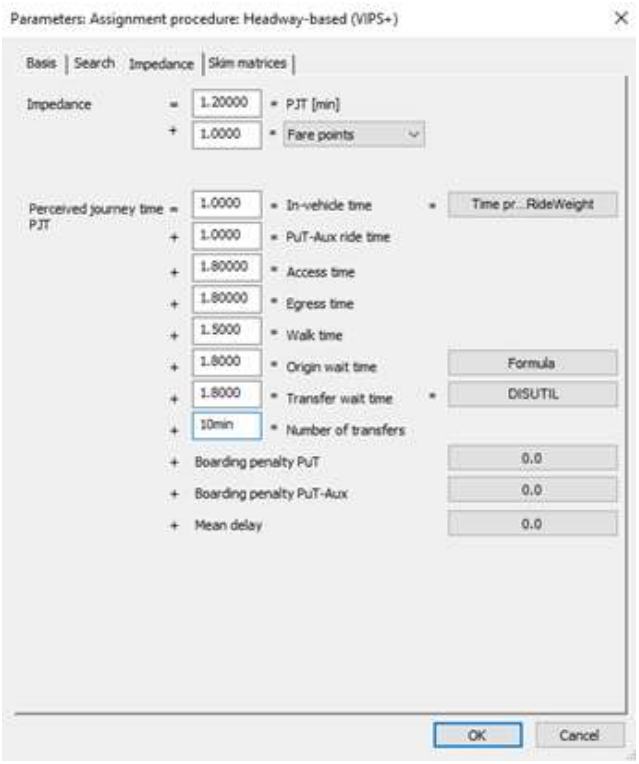


Figure 4.3: The headway-based assignment impedance

Once the impedance is defined, the assignment variables will be generated by executing the assignment process. It should be noted that, the more the number of zones, the slower the analysis process.

4.2.6 Reference results

In this stage, the output of assignment for particular scenario will be obtained; a schematic diagram is shown in Figure 4.4. The reference scenario is considered as a "Do nothing" scenario. The demand and supply will be referred to 2016 then to 2025 to search the possible ways for improving the present and future condition.

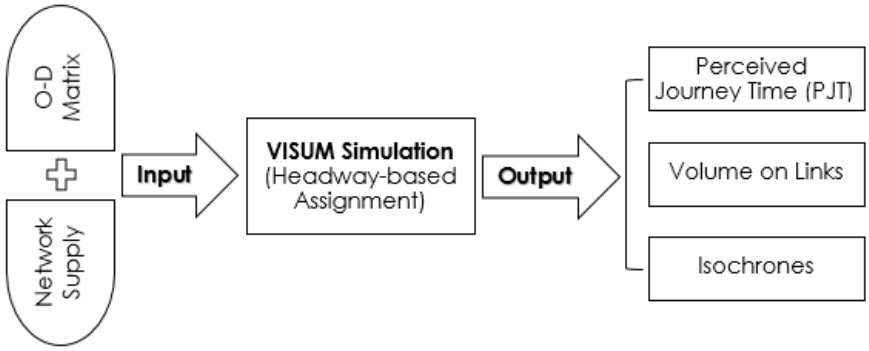


Figure 4.4: Input-output data of VISUM

4.2.7 Data change and create new scenario

To get the assignments result for different scenarios, the input data needs to be changed, and the assignment model will be run as stated above. The major data to be changed here is demand $O-Dmatrix$, the speed for means of transport, $etc.$

After doing all these, the same procedure for data analysis then reference results will be followed until to get the results better than that of reference scenario (Present condition).

4.2.8 Conclusions

Once all the procedures described above are implemented, the final step is to make justification about the alternative results we got. $Finally$, one alternative will be found as the best one among all alternatives and will be further studied.

Chapter 5

Network Configuration and Seclection of Alternatives

5.1 Network Configuration

A transportation network is typically referred to a set of nodes, links, stations, lines, etc. In this study, the public transport network of Kabul was created in VISUM. A brief description to the network configuration is given in in the following sections.

5.1.1 Creation of network elements

Using the network editor menu of VISUM shown in Figure 5.1, the public transport network was created.

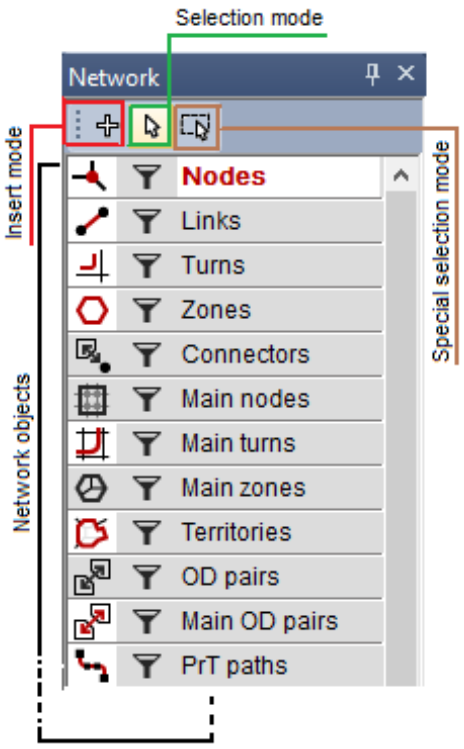


Figure 5.1: Network editor menu in VISUM

Zones

After properly opening the VISUM file and using the zones menu, Kabul territory map with 22 zones was created. To create zones first, make sure that the layer of Zones (shown in Figure 5.1) then the insert mode are both on. After that, you will be asked for clicking on the VISUM page to determine the location of your zone centroid. By clicking on the screen, you determined the zone centroid. Furthermore, a dialogue box will appear asking you for zone name and number. Name and number of zones are optional (for our case zone 1-22). Later, the attributes for each zone were properly introduced. The zone centroid later can be replaced to anywhere you want.

Nodes and links

Node is the primary component of the transportation network, which may be an intersection, junction, station, stop point, starting or beginning point of a link, etc. Once all the zones are created, the next step is to insert all network related nodes. The procedure for inserting node is same as the zones. Similarly, after inserting the nodes; all the links were created using the same procedure discussed above. Attributes of the links were properly introduced.

Lines

Using the lines menu, 54 lines for public transport network with the ten terminals throughout the Kabul were properly created. The directions “up or down” were mentioned such that, the origin of the proposed integrated line is Company Chowk and the destination is Bot Khak. It means that line route from origin towards the destination is mentioned as direction “up” and the vice versa is direction “down.”

Stop points

Each line route consists of some stops point for boarding and alighting passengers. Stop points were inserted to VISUM with the distance ranging from 300-500 meters depending on the existing land use pattern.

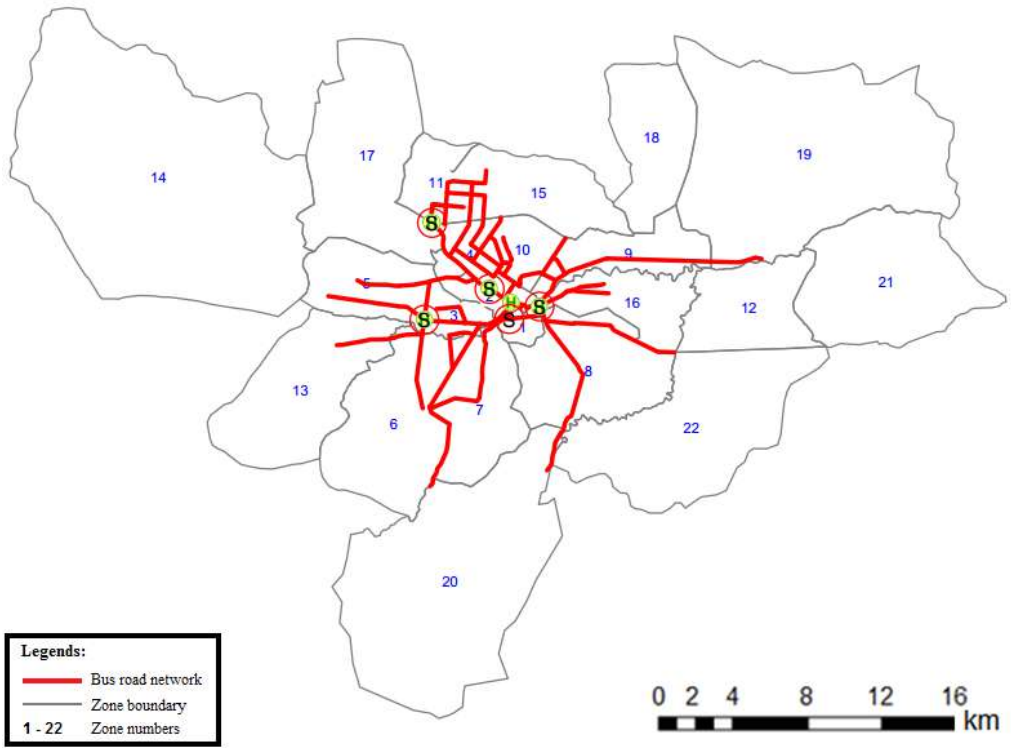


Figure 5.2: Public transport network of Kabul created in VISUM

5.2 Selection of alternatives

The main task in this section is to suggest different alternatives (variants) for the public transport system. We are going to find some optimal solution for improvement of the public transport system for today, then for the future. From the literature survey, we understood that the present condition of the Public transport system is too harmful to the people. That is why we are going to do some analysis for improvement of the public transport for today and future. Although the solution for today's transport system may not be practical, we want to show that using proper tools and methodologies the week transport networks can be analyzed for any given time; which would lead to huge improvements with the minimal cost and time.

From the screen line survey, it was found that more daily trips within the Kabul city are generated and attracted along the east-west axis rather than others so that we will study the route from Company Chowk to Bot Khak. Also due to the existence of mountains in Kabul city and looking at the Green Urban Transport Strategy of Afghanistan (GUTSA), construction of new roads rather than improving the existing transport condition cannot solve today's problem; because of land use problem, tunnels required and time taking to implement the big projects. Hence, we first try to overcome the problems that exist today by improving the available transport network rather than going for construction of the new one. Then, the future planning for functional polycentric transport system will be studied. Working in VISUM needs some characteristics to be introduced for the proposed line (new line). The

next section provides the criteria for selecting alternatives, and the values chosen here.

5.2.1 Distance between stops

In the design of the line, by average the distance between two successive stops should be fixed. Two main alternatives will be studied as follows:

(1) Line with more number of stops along the itinerary (present condition)

(1) Line with more number of stops along the itinerary (proposed condition)

Figure 5.3 illustrates these two alternatives.

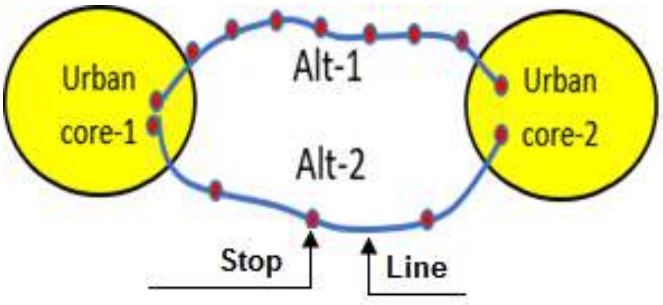


Figure 5.3: Lines with different number of stops

Each alternative will further consist of two more sub-alternatives say route line with more stops and second is a route with fewer stops than the first one shown in figure 5.2. The following section states the alternatives chosen here.

5.2.2 Means of transport

Typically in the public transport system, the distance between stops is bounded with the mean of transport. So, the means of transport for each alternative in 2016 and 2025 is given in the below lines respectively:

For the year of 2016:

(1) Vehicles with low top speed will be the mean of transport for Alternative-1 (Present bus lines).

(2) Vehicles with medium top speed will be the mean of transport for Alternative-1 (lines with large buses).

For the year of 2025:

(1) Vehicles with low top speed will be the mean of transport for Alternative-1 (Present bus lines).

(2) Vehicles with more top speed will be the mean of transport for Alternative-1. (BRT, LRT, City rail).

Unfortunately, the city public transport is served only by bus lines; and no more lines for BRT and LRT is open for operating. So, the means of transport for alternative-1 and alternative-2 in 2016 will be the present bus lines, and the bus lines with large buses respectively; while for alternative-2 the present lines and BRT would be respectively. The capacities and speeds of different vehicles introduced for VISUM are given in Table 5.1.

Table 5.1: Capacity and speeds of different vehicles

Means of transport	Speed (kph)	Used for	Year
City current buses	10	Alternative-1	2016 & 2025
Large buses	20	Alternative-2	2016
BRT	30	Alternative-2	2016

5.2.3 Alternative-1

Alternative-1 is taken as today's existing plan of public transport network for Kabul for monocentrism consisting of bus lines with the distance between stops around 400 m. It is likely for people because of being more accessible for users to get a bus with reduced walk, in another hand with more journey time. From the O-D rips table also future growth of the trips, some of the urban cores were found located in district 5, 2, 8, 12, 21 and 22 (New city of Kabul is not mentioned here). Furthermore, the screen line survey conducted by (JICA, 2009) it is clear that the "Jadayi sehi Aqrab" road which connects district 14, 5, 3, 13, 6, 7 to district 2 (city center) carries the highest volume of traffic "49800" PCU per 12 hrs in both directions during the period (7 am to 6 pm) also the district 21, 22, 18 and 19 in which the desired growth rate of generation is high compared to others. It is essential to study the lines (L55, L15, and L112) and continue the itinerary to connect district 21. All the said lines are consisting of few large buses, minibuses, microbuses and taxis with poor services. The chosen values were given in Table 5.1. This alternative consist of sub altrnative1.1 and 1.2 stated below:

Alternative-1.1

This Alternative with the total line route length of 30.394 km consists of the line route L55, L15, and L112 and route from Bot Khak Chowk (district 12) to Bot Khak (district 22) shown in figure 5.4.

Figure 5.4: Line route for alternative-1.1

Alternative-1.2

This Alternative with total line route length of 38.442 km consists of the line route L55, L15 and L212 also route from Bot Khak Chowk (district 12) to Bot Khak (district 22) shown in figure 5.5.

Figure 5.5: Line route for alternative-1.2

5.2.4 Alternative-2

Alternative-2 consisting of the same line routes as alternative-1 but with reduced number of stops increased top speed of $20 and 30 kph$ for the year $2016 and 2025$ respectively. It will be the planning which simultaneously supports the improvement of the today's poor condition of the public transport also the polycentrism in Kabul due to the reduction in travel time. It will be attractive for the users. The stops meeting the following criteria are removed from each sub-alternative:

(a) Sum for boarding and alighting of the passengers in the stop to be minimum

(b) Distance between successive stops on the route are > $800\ m$

Considering the present problems of using the public transport for both the users and operators in Kabul it was decided to use bus lines. Alternative-2.1 has the same route as Alternative-1.1 with the total length of 30.394 km. Also, Alternative-2.2 has the same route as Alternative-1.2 with total length of $38.442 km$.

Chapter 6

Results and Discussions

6.1 General

The results for both the main two alternatives will be analyzed and compared in the following sections. Each set of the main tow alternatives will be considered for analysis in the base year 2016 and for the target year of 2025, to see what can help us for improvement of the present as well as future condition.

6.1.1 Results and analysis

The results will be analyzed by comparison of the following three measures with the reference scenario then between each alternative and sub-alternative to find the best one among all:

- Column Charts (Boarding, Alighting and Through Passengers) on each particular stop.
- Total volume of passengers per each line route
- Total Perceived Journey Times (PJTs) of passengers per zones

Once all results are obtained, they will be compared such that, the alternative meeting less PJT, increase of passengers volume on each line route, and more passengers boarding, alighting, and going through each stop of each alternative will be chosen as best alternative among all.

The alternative found as the best one will be further studied to find the frequency of the line for different comfort levels. The following four comfort levels will be considered here:

- Maximum capacity (seating 100% + standing 100%)
- Bad comfort (seating 100% + standing 40%)
- Fairly good comfort (seating 100% + standing 20%)
- Good comfort (seating 100% + standing 0%)

6.2 Comparison of the Alternative (2016)

In this section all the alternatives will be compared with the reference scenario as well as among themselves based on the criteria stated above.

6.2.1 Alternative-1.1 versus Reference Scenario

Column Chart

Figure 6.1 illustrates the column chart for direction "up". Column chart for direction "down" has the same structure as "up". From the column chart, the maximum number of passengers going through has increased from 598 to 962 persons compared to the reference scenario. It is a good change in planning. Important stops with high boarding and alighting rate are visible from the column chart as well.

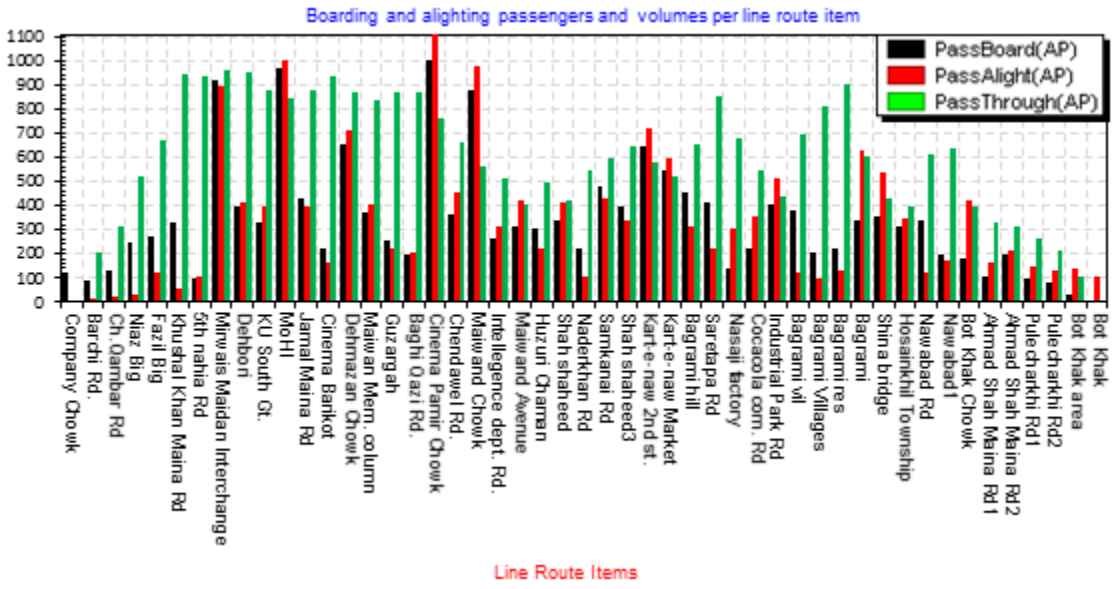


Figure 6.1: Column chart for alternative-1.1, Direction "up"

Volume of passengers on each line route

The volume of passengers shows more improvement compared to reference scenario in the Huzori Chaman - Bagrami hill – Bot Khak Chowk, then Bot Khak. It means people are more interesting using this line compare to reference scenario (using four line routes from origin to destination).

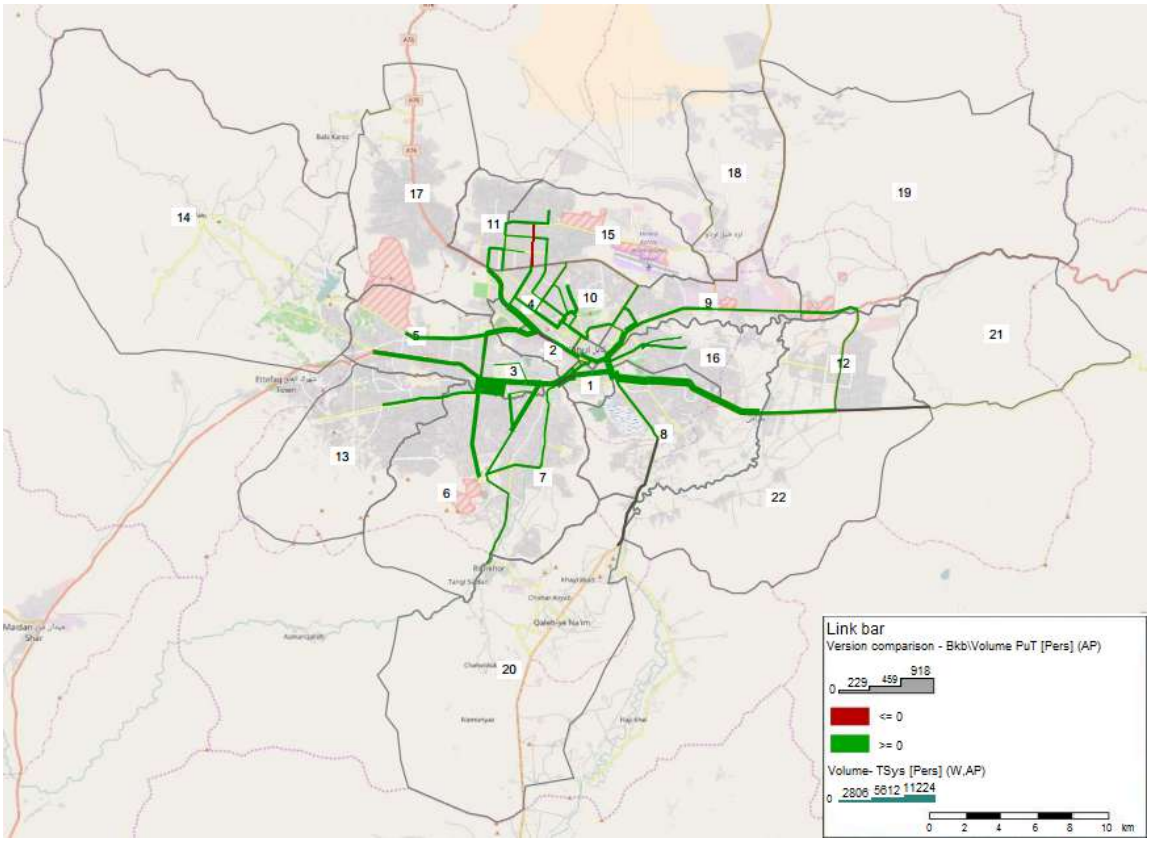


Figure 6.2: Volume on each line route for alternative-1.1

Perceived Journey Time

The difference between perceived journey times for all the alternatives are shown in Table 6.1.

Table 6.1: Comparison of the TPJT for all alternatives

Alternatives	TPJT of alternative (i) - TPJT of alternative-1.1
Reference scenario	-1522
Alternative-1.1	0
Alternative-1.2	-124
Alternative-2.1	327
Alternative-2.2	-105

On the basis of criteria stated above, the alternative-1.1 was found to be better than the reference scenario. In next section, the same comparison will take place for alternative-1.2 versus alternative-1.1.

6.2.2 Alternative-1.2 versus Alternative-1.1

Column Chart

From column chart for direction “up” it was seen that the maximum number of passengers going through has decreased from 962 to 911 persons that of alternative-1.1. The column

chart of direction “down” has the structure same as “up”.

Volume of passengers on each line route

An improvement of passenger volume occurred in the Mahmood Khan Bridge - Pulchakhi, then Ahmadshah maina (district 12), but the volume of passengers travel from other zones using this route especially from district $6, 7, 14, 20, 22$ are too less compared to alternative-1.1. For the east-west axis public transport route point of view, it is essential the mentioned districts be benefited, which is too less in the case of alternative-1.2.

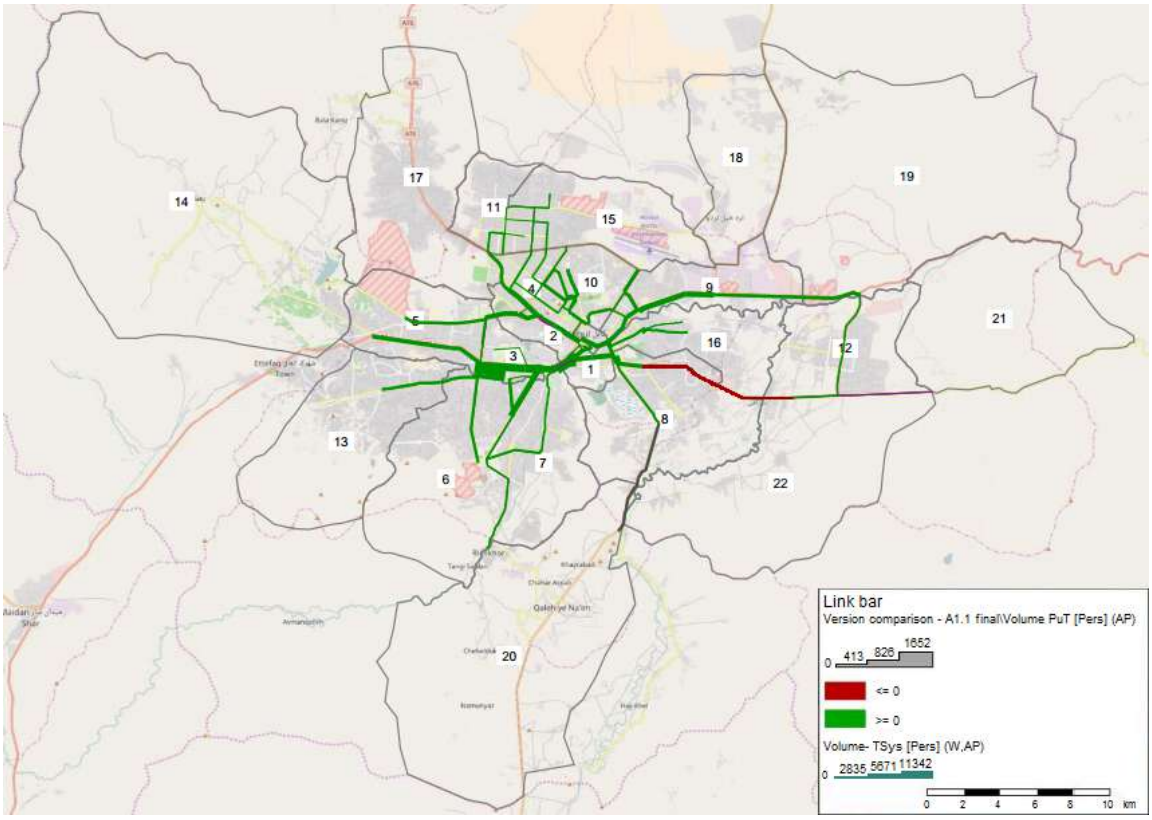


Figure 6.3: Volume on each line route for alternative-1.2

Perceived Journey Time

Perceived journey times are shown in Table 6.1. Hence, from the decrease in passengers going through, less volume improvement in the desired districts, and more PJT compared to alternative-1.1 it was found that alternative-1.1 is better than alternative-1.2.

Alternative-2.1 versus Alternative-1.1

The alternative-2 will be compared for the same line route with alternative-1, it means that we are going to know the effect of the new way of planning.

Column Chart

Column chart for direction "up" and direction "down" can be seen from below Figures. The maximum number of passengers going through has increased from 962 to 1864 persons (Almost twice). The main reason for this improvement is high speed and accessibility of bus from any origin to any destination along the mentioned line. It is a very good change in this method of planning. Important stops with the high boarding and alighting passengers are visible from the column chart as well.

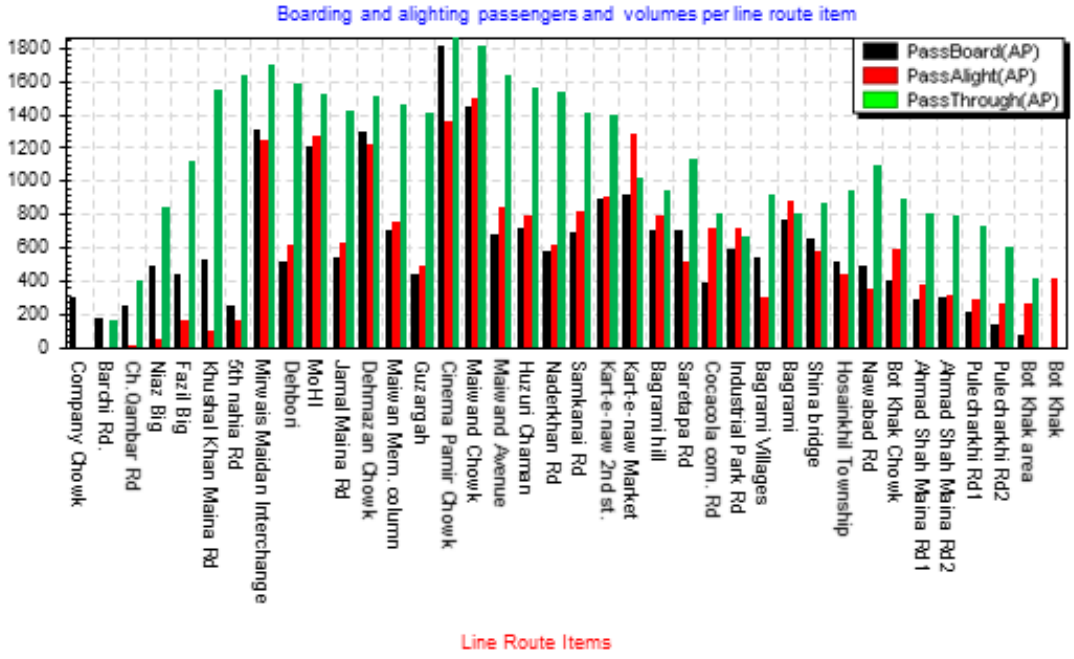


Figure 6.4: Column chart for alternative-2.1, Direction "up"

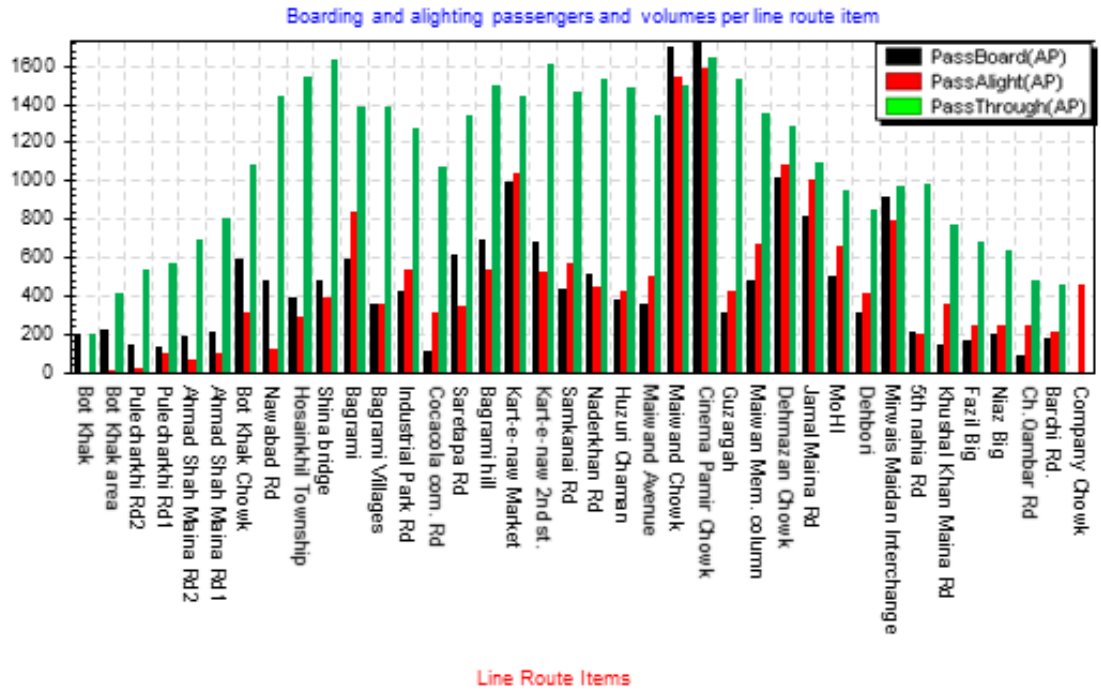


Figure 6.5: Column chart for alternative-2.1, Direction “down”

Volume of passengers on each line route

Huge volume improvement occurred along whole the route especially from Bot Khak Chowk to Bot Khak which was always less in the case of other alternatives. Furthermore, a good volume improvement also occurred in the southern districts while average improvement is achieved in the north-eastern to north-western sides.

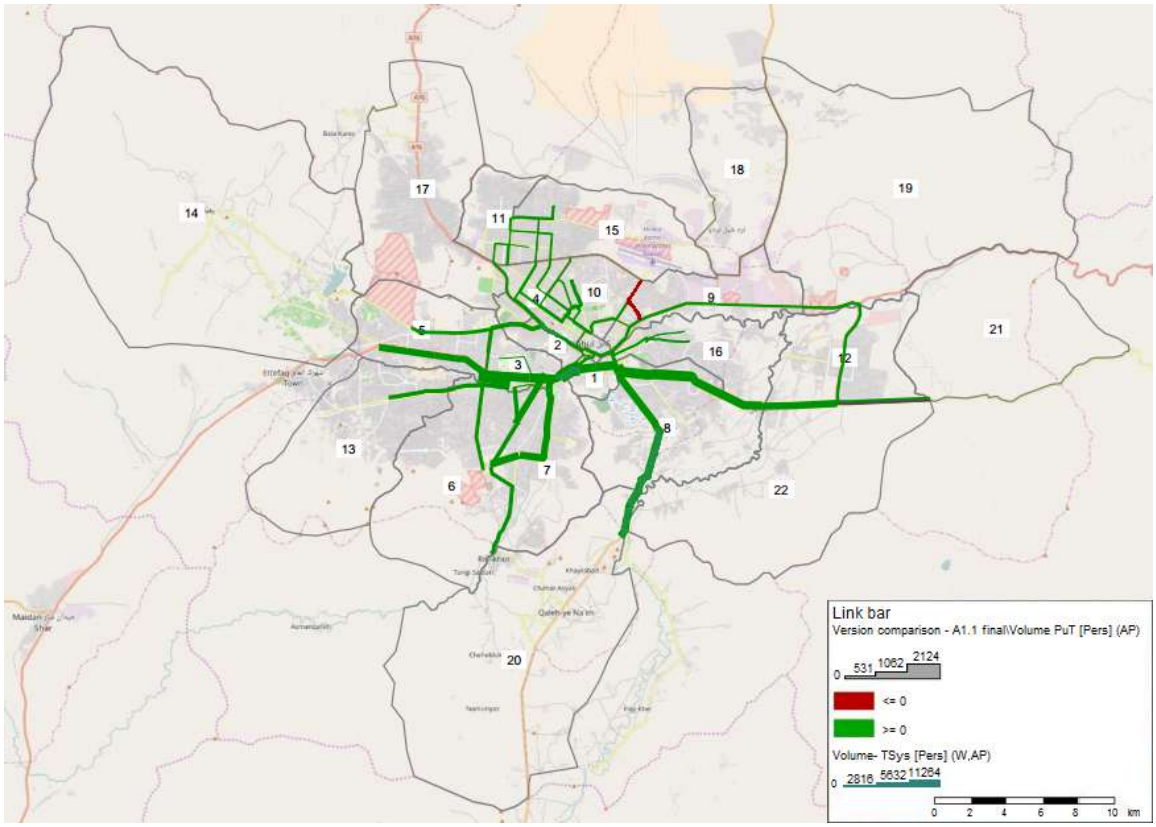


Figure 6.6: Volume on each line route for alternative-2.1

Perceived Journey Time

Perceived journey times are shown in Table 6.1.

6.2.3 Alternative-2.2 versus Alternative-1.2

Column Chart

Column chart for direction "up" can be seen from Figure 6.7. The column chart of direction "down" has the same structure as "up". The maximum number of passengers going through has been increased from 911 to 1637 persons per four hours. It is very good change by $alternative - 2.2$, but after comparison of volume and PJT, it will be decided whether this is the best of alternative-2.1.

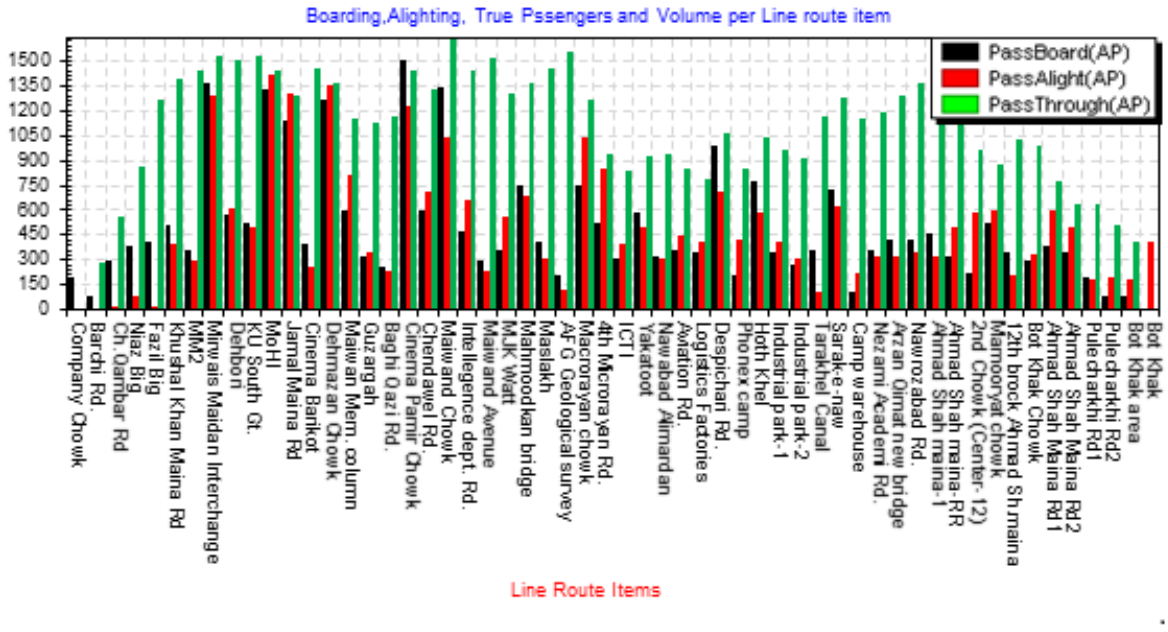


Figure 6.7: Column chart for alternative-2.2, Direction “up”

Volume of passengers on each line route

From one hand, a good volume improvement occurred for the line route form Pulmahmood Khan to Pulcharkhi road, and fair improvement in the Ahmadshah maina area. From another hand, this improvement is too less in other parts of the city and urban-cores. It is not a good decision to adapt the network for that high demand of that particular area because the user cost will more increase which is not a good practice in transportation planning. The district $6, 7, 82021, and 22$ shows decrease in volume of passenger for such planning.

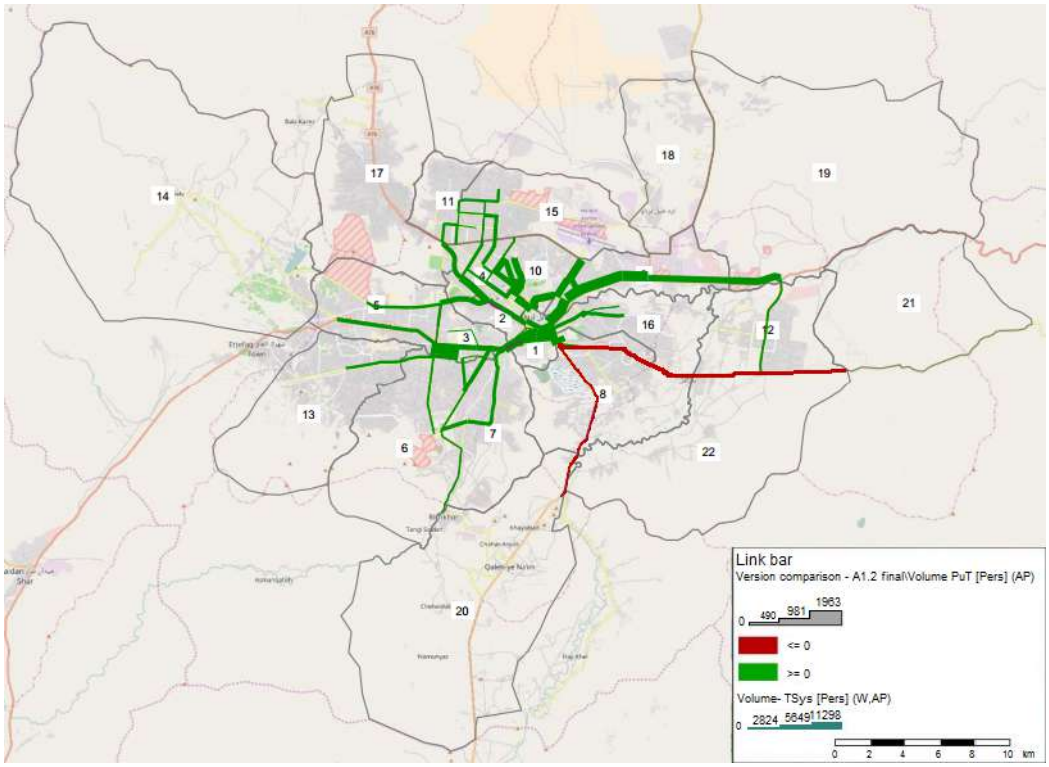


Figure 6.8: Volume on each line route for alternative-2.2

Perceived Journey Time

Perceived journey times are shown in Table 6.1.

6.3 Comparison of the Alternatives (2025)

In this section all the alternatives will be compared same as in 2016. We are going to show the column chart only for the selected alternative.

6.3.1 Alternative-1.1 versus Reference Scenario

Column Chart

From the column chart , the maximum number of passengers going through has increased from 598 to 1928 persons compared to the reference scenario. Good change in planning.

Volume of passengers on each line route

The volume of passengers shows more improvement compared to reference scenario in the Kart-e-naw - Bot Khak. It also shows a little decrease on the Pule charkhi road. It indicates attractiveness of the line route.

Perceived Journey Time

The difference between perceived journey times for all the alternatives are shown in the below Table.

Table 6.2: Comparison of the TPJT for all alternatives

Alternatives	TPJT of alternative (i) - TPJT of alternative-1.1
Reference scenario	-6957
Alternative-1.1	0
Alternative-1.2	-1423
Alternative-2.1	674
Alternative-2.2	518

6.3.2 Alternative-1.2 versus Alternative-1.1

Column Chart

Here, the maximum number of passengers going through has decreased from 1928 to 1787 persons compared to the alternative-1.1.

Volume of passengers on each line route

Volume of passengers has improvement on the Pule charkhi and Ahmad Shah Maina road, but more decrease on the Kart-e-naw road as well as the routes to $district 7, 8, and 22$ compared to the alternative-1.1. It shows the relative deduction in volume, while the target route is remain unserved.

Perceived Journey Time

Table 6.2 provides the difference between perceived journey times for all the alternatives.

6.3.3 Alternative-2.1 versus Alternative-1.1

Column Chart

A huge increase in the maximum number of passengers going through has occurred in this comparison. Compared to the alternative-1.1, it shows increase from 1928 to 2958 persons. It is really great change in volume, and indicates the proper attractiveness of the planning by this way. Column chart is shown in the below Figure.

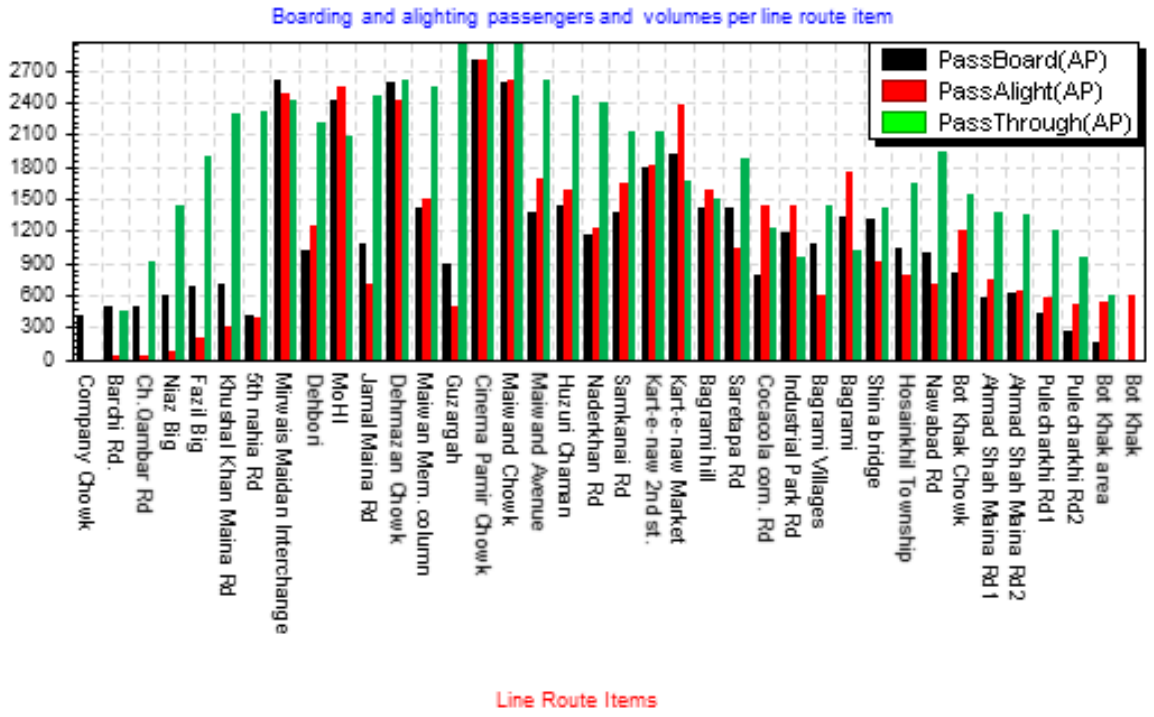


Figure 6.9: Column chart for alternative-2.1, Direction “up”

Volume of passengers on each line route

Volume of passengers has improvement on the Pule charkhi and Ahmad Shah Maina road, but more decrease on the Kart-e-naw road as well as the routes to $district 7, 8, and 22$ compared to the alternative-1.1. It shows the relative deduction in volume, while the target route is remain unserved.

Perceived Journey Time

Table 6.2 provides the difference between perceived journey times for all the alternatives.

6.3.4 Alternative-2.2 versus Alternative-1.2

Column Chart

Here, the maximum number of passengers going through has increased from 2351 to 1787 persons compared to the alternative-1.1.

Volume of passengers on each line route

Volume of passengers has further improved on the Pule charkhi and Ahmad Shah Maina road.

Perceived Journey Time

Table 6.2 provides the difference between perceived journey times for all the alternatives.

6.4 Discussions

The results of two main alternatives were compared with each other as well as the reference scenario for both the years 2016 and 2025. In alternative-1, first of all the alternative-1.1 was compared with the reference scenario then with alternative-1.2 as per the criteria stated above. The sub-alternative-1.1 was found the best. Similarly, the alternative-2 was compared with the same line route as in the alternative-1.

Finally, from comparison among all alternatives the alternative-2.1 $(planningforpolycentrism)$ was found to be the best among all $(alternative-1and2)$ for both the base and target years; because from comparison of alternative-2.1 versus alternative-2.2 with respect to criteria stated above, it is clear that the alternative-2.1 has lessPJT, more volume of passengers and more boarding and alighting of passengers in each particular stop compared to alternative-2.2.

Hence, alternative-2.1 is the best alternative among all with the 327 and 674 hours difference (reduction) in PJT, increase in the number of passengers going through from 1637 to 1864, and 2958 persons per four hours in the direction up, and the improved volume of passengers along the proposed line route was chosen as best one among all for the base year of 2016 and target year 2025 respectively.

In this new line, the maximum number of passengers per four hours is 1864 in the direction up and 1728 passengers in the direction down for 2016, while it is 2958 in the direction ”up” for 2025. Assuming the peak hour occurs in this four hours, so for direction up the 583 passengers per hour will be the number to work with in 2016. On direction down, there are 432 passengers per hour, and it can be increased to 540 in the rush hours. To satisfy the demand, the frequency should be increased to from 20 to 5 minutes in the peak hour in both the directions “up & down” and 6 minutes in rest of the day in 2016.

Although, the increase in distance between the stops increases walk time for the passengers. So, this will be rectified by using the feeder services connecting the suburbs to stations. It will reduce the congestion as well.

Here, the number of buses will be calculated for all comfort levels shown in next Table as per 2016. Keeping the capacity of the bus for BRTS as $90passenger$, and using the same methodology, the frequency of line, and number of basses for different comfort levels can be calculated for the year 2025.

Table 6.3: Number of passengers per hour for each vehicle type

Unit: Passenger		Vehicle type	Large bus (Millie bus)	Minibus (Coasters)	Microbus (Town ace)	Taxi
		Capacity (Seating Passengers)	36	20	8	4
		Capacity (Standing passengers)	24	5	0	0
		Total capacity (Seat+ Standing)	60	25	8	4
Comfort Level	Headway (min)	Frequency (No. of Vehicles /hr)	No. of Passengers/hr			
Maximum capacity	6	10	600	250	80	40
	5	12	720	300	96	48
Bad comfort	6	10	456	220	80	40
	5	12	547	264	96	48
Fairly good comfort	6	10	408	210	80	40
	5	12	490	252	96	48
Good comfort	6	10	360	200	80	40
	5	12	432	240	96	48

Chapter 7

Summary, Conclusions, and Recommendations

7.1 Summary and Conclusions

An attempt was made in order to study what should be the best way to improve the public transport network in the suburbs, making the multiple-core structure more functional and stronger. The city is growing by around $100,000$ people per year and it makes necessary to adapt the public transport network to this fact in order to get a more cohesive city with strength connections between the urban-cores. Kabul city master plan is also focusing on this task, trying to plan more integrated suburbs with reinforced connectors and to further develop a dense, multi-center capital region.

Thus, Kabul needs to develop a good public transport system to support a polycentric and densely populated structure. In this study both the political and technical interests are taken into consideration. Kabul is being more polycentric but this does not only mean that there are some differences in the density pattern (there are a lot of urban-cores). It is needed that these cores represent real unifying elements of urban subsystems. This difference was shown in the literature review when Madrid and Barcelona were compared.

Madrid has a lot of suburbs (see metro network map) but they are not specialized to attract people of other cores. Barcelona, on the other hand, has the same number of outer cores than Madrid but they can work by themselves. That is why Barcelona was considered a polycentric city and Madrid not. Kabul nowadays is closer to the structure of Madrid than that of Barcelona.

The city should be planned in a future being aware of this situation. urban-cores of Kabul have almost the same structure and need to be developed in different ways to attract more people of other suburbs. This development will avoid travels to the city center that will help reducing congestion problems that exist currently. In short, and according to CRIDA, the outer cores need to become more metropolitan in character. But also, improving the accessibility is a prerequisite for this development in the regional-cores. Integrated line like that is planned here will help to strength this connection between the outer parts of Kabul.

After the comparison of $maintwo$ alternatives, it was shown that planning for

polycentrism has more advantages than the plan that exist today. Travel times were reduced and it attracted more people. Also, the number of users will be more in the future because as said before. This program does not take into consideration people that could change their travel habits and would choose traveling by public transport instead of car if the new line is attractive enough.

gives more accessibility to the people who live between cores because it has more stops but the travel time increases and it does not help to the polycentric concept. Therefore, this alternative does not support the polycentrism. A vehicle with higher speed is really needed if the connections between urban-cores are wanted to be improved.

gets more passengers crossing the northeast-southwest axis of Kabul than the other alternatives and the amount of travelers between north-southern axis is well-balanced. It also increases the travels among suburbs and decreases the amount of people that travel to the city center, what helps avoiding congestion in the inner city.Perceived journey time is reduced quite enough compare to reference scenario; While the costs decreased because the new line is an integrated bus line for 2016, and line for 2025 which follows the route of other buses and private cars that already do these routes. The problem of this alternative compared with the alternative-1 is that people who live between cores have fewer facilities to use this line. Thus, to make this line working better, it is necessary to have some lines that work as feeders to the main proposed line.

7.2 Recommendations

Following sections provide some of the recommendations which may help the public transport sector of the Kabul city as well as other cities.

7.2.1 Transportation Demand Studies in Sustainable manner

Demand analysis is the key part of the public transportation system lack of sufficient information about all the major factors especially the technical, and socio-economic data sets may lead the planning towards unexpected direction. It is recommended that the concerned employees of the departments/ministries dealing with transportation to be properly trained; and they should be capable of demand data collection and process. From one hand it will lead to attract the specialist in each sector; from another hand the data sets will be more accurate than predicted data.

7.2.2 Expansion of moder bus services to all urban-cores and newly developed areas

Providing the modern Bus services equally to all the areas to satisfy the role of public transport. The ticketing system to be changed from manual to automatic which would

help for understanding number of passengers boarding and alighting; operating time from morning proper time to late night (as the demand exist).

7.2.3 Improving of the Fare structure

The fare structure is still fixed fare. It may be changed from fixed fare to distance-based structure, this change will further encourage the people to chose buses which leads to maintain the optimal user cost as well as operator cost.

7.2.4 Improvement of public transport services

Provision of the better services would further attract the passengers and improve the operational revenue. The key indices of services to be improved include expansion of bus service network, assuring speed and punctuality, provision of comfortable vehicles and waiting spaces, provision of high frequency and suitable operation hours, and adequate fare system. In view of the present conditions of bus services in Kabul, the expansion of bus network to provide the services equally to all areas as well as the improvement in speed and punctuality to raise the credibility as public transport are most important factors. However, improvement exceeding the range of adequate fare system will obstruct the effective operation. Improvement of operational efficiency is essential.

7.2.5 Improvement of operating efficiency

It is necessary to study how to provide equivalent services to all the areas with minimal cost without lowering the overall service quality. The key factor will be provided measures to assure the equivalent transportability at minimum cost, covering the entire service area.

7.2.6 Reduction of adverse impact on road traffic conditions

Traffic congestion is a major issue in the Kabul city especially during the morning and evening peak hours. If the bus operation including traveling, stopping and waiting obstructs traffic on the roads, justification for improvement of the traffic conditions is lost. Measures to satisfy the spatial requirements for traveling as well as stopping are most essential.

Scope for Further Research

This is not the end of road. Following researches can be done in future:

- The same methodology can be applied for other polycentric cities or the cities tending to transform to a polycentric shape.
- Same methodology with the timetable-based assignment can be more effective for the lines with low frequency.

- To consider the passenger satisfaction level.
- To further improve the weights of the PJT components given in equation (4.2).
- To use the base year demand data.

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