AMERICAN UNIVERSITY OF BEIRUT

TRANSPORTATION POLICIES: COUPLING BEIRUT BUS RAPID TRANSIT AND CONGESTION CHARGE

by
MAZEN MAHMOUD SLEIMAN AL CHEIKH

A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Science
to the Department of Mechanical Engineering
of Maroun Semaan Faculty of Engineering and Architecture
at the American University of Beirut

Beirut, Lebanon
January 2022

AMERICAN UNIVERSITY OF BEIRUT

TRANSPORTATION POLICIES: COUPLING BEIRUT BUS RAPID TRANSIT AND CONGESTION CHARGE

by

MAZEN MAHMOUD SLEIMAN AL CHEIKH

Approved by:

____

Dr. Nesreene Ghaddar, Professor
Department of Mechanical Engineering — Advisor

____

Dr. Hassan Harajli, Lecturer
Department of Mechanical Engineering — Co-Advisor

____

Dr. Kamel Aboughali, Professor
Department of Mechanical Engineering — Member of Committee

____

Dr. Harith Abdulsattar, Assistant Professor
Department of Civil and Environmental Engineering — Member of Committee

Date of thesis defense: 26 January 2022

AMERICAN UNIVERSITY OF BEIRUT

THESIS RELEASE FORM

Student Name:__SLEIMAN AL CHEIKH___MAZEN_______MAHMOUD____
Last First Middle

I authorize the American University of Beirut, to: (a) reproduce hard or electronic copies of my thesis; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes:

☐ As of the date of submission

☒ One year from the date of submission of my thesis.

☐ Two years from the date of submission of my thesis.

☐ Three years from the date of submission of my thesis.

__________________02 / 02 /2022_______________

Signature Date

ACKNOWLEDGEMENTS

I offer my gratitude first of all, to Dr. Hassan Harajli, for his support to work on this subject, for his guidance and because he believed in me. Without his encouragement, I couldn't proceed with this exciting topic.

Also, I would like to thank Dr. Ghaddar, for her continuous support and follow-up during my time in AUB. She provided us with a comfortable environment to learn and acquire knowledge. Thanks as well to the committee members Dr. Aboughali and Dr. Abdulsattar for their important inputs and to be part of this thesis committee.

A special thanks to Ms. Lara Khoury for her kind support during my master's time.

Also, I would like to thank all my colleagues who supported me during this path, especially Dr. Sorina MORTADA for her continuous encouragement to join the masters in the first place and my friend Ghadi Tlayji for reviewing my thesis several times.

Finally, not to forget my family who has played a major role in helping me to finish this thesis.

ABSTRACT
OF THE THESIS OF

Mazen SLEIMAN AL CHEIKH for Master of Science
Major: Energy Studies

Title: Transportation Policies: Coupling Beirut Bus Rapid Transit and Congestion Charge

The Lebanese Transport sector is highly dependent on private cars. This fact made the sector energy-intensive. It is the second large energy consumer in Lebanon, only after power generation. Plus, it accounts for 23% of the national Green House Gases emissions. The Greater Beirut Area is Lebanon's transport hub due to its position on the T-section linking the coastal road and Beirut-Beqaa Road.

This thesis evaluates the mobility parameters, (city and transport system chracteristics, and transport externalities), in GBA. As expected, public transportation is highly needed to present an alternative for passengers. In addition, A national framework has to be established. A job centralization within both Beirut district and GBA create a flow from different region toward this key area.

Beirut Buses Rapid Transit (BBRT) project is presented as a solution for mobility in GBA. Or, through an economic analysis, it appears that this project requires 50 million USD subsidies only in the first year, which makes it economically unsustainable. The proposed solution is to introduce a transport policy in order to make a modal shift from private cars to the BBRT and at the same time collect revenues that can be diverted to finance the project. Through policy analysis, the congestion charge was the appropriate choice. The coupling of the Congestion charge and BBRT has proven to be successful. At a fee of 0.5 USD, the congestion charge made the project profitable from the first year. The shifting passengers have covered the deficit in the BBRT budget. The coupling also presented an environmental advantage, with both projects alone, achieving 3% of Lebanon NDC’s GHG reduction target. Still, Social equity has to be addressed as well and additional measures should be studied.

TABLE OF CONTENTS

LIST OF FIGURES

Figures

TABLES

Tables

ABBREVIATIONS

US: United States of America

EU: European Union

SDGs: Sustainable Development Goals

GDP: Gross Domestic Products

GBA: Greater Beirut Area

UN: United Nations

MDG: Millennial Development Goals

GHG: Green House Gases

Pkm: Passenger Kilometers

Tkm: Tones Kilometers

NMT: Non-Motorized Transport

PT: Public Transport

TP: Transportation Policies

SWT: Strengths, Weaknesses, Opportunities and Threats

PEST: Political, Economic, Social and Technological.

CC: Congestion Charge

LEZ: Low Emissions Zone

UK: United Kingdom

PM: Particulate Matter

BBRT: Beirut Buses Rapid Transit

UNFCCC: United Nations Framework Convention on Climate Change

AUB: American University of Beirut

USD: United States Dollar

LBP: Lebanese Pound

IBRD: International Bank for Reconstruction and Development

GCFF: Global Concessional Financing Facility

EIRR: Economical Internal Rate of Return

MOE: Ministry of Environment

MOEW: Ministry of Energy and Water

RPTA: Railway and Public transport authority

TAVMA: Traffic and vehicle management authority

MSCP: Marginal Social Cost Pricing

CAPEX: Capital Expenditure

OPEX: Operating Expenses

NDC: Nationally Determined Contributions

CHAPTER 1

INTRODUCTION

In a world of fast development and rapid rhythm, moving around is essential on a daily basis. Speed and Cost are the first qualities to search for, in any means of transportation. This is, to a certain degree, acceptable on the individual level. For users, transportation is a service, on the way to its main objective: health service, education, Job... On the governmental level, the picture is more complicated. Linking city districts and cities together became essential, to connect different stakeholders and enhance economic growth. Still, it is one side of transportation implications. There are additional social impacts of new transportation project. Mobility is a privilege, and it must be accessible to all. Environment as well is affected by transportation. Air pollution and sustainability are heated problematics worldwide, especially in urban areas.

For more clarity, the transport sector was directly responsible for 8.2 $GtCO_2$ emissions in 2018, which is equivalent to **24% of CO_2 emissions** from fuel combustions. Figure 1 presents the energy portfolio of transport worldwide. Mobility is highly dependent on oil resources and it consumes **27.7% of all end used energy** worldwide [4]. These numbers pushed mobility to the top of the sustainability transition list. On the social side, **one person out of three**, living in rural area worldwide have no access to transportation services in 2006 [6].

Demand for transport is in continuous increase. It is forecasted to have, by 2040, 2.3 times more need for mobility than 2019 (Figure 2). To meet this need, decision-makers must tackle the sector from a broader point of view. The transport system must be divided in two main parts: infrastructures and governance. And these two branches must be well optimized, together as one package, to respond to the different challenges cited above (economic, social, environmental…).

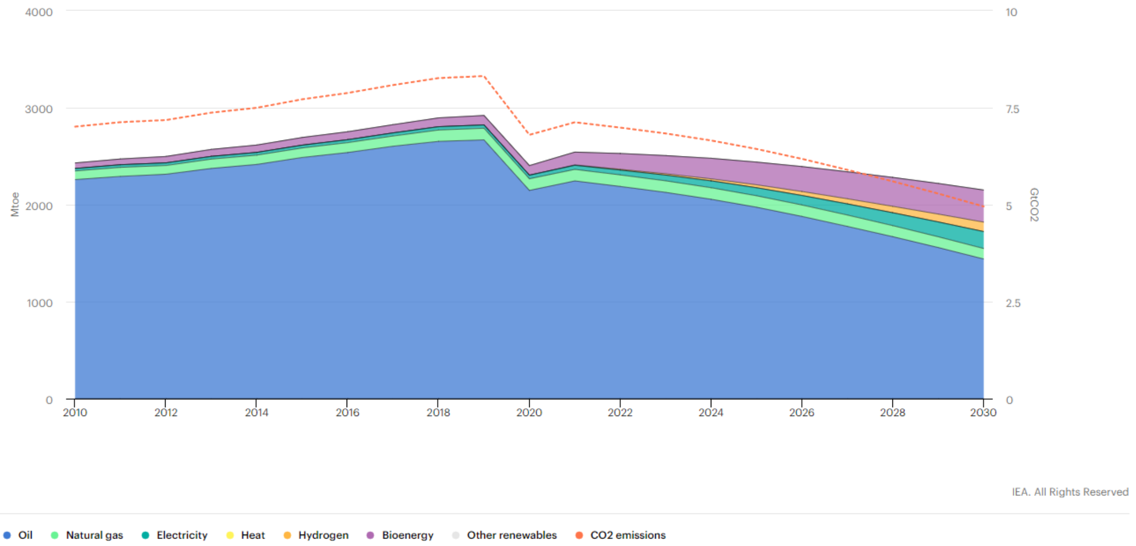

Figure 1: Final Energy Consumption of the Transport Sector, assumption in a sustainble scenario. [4]

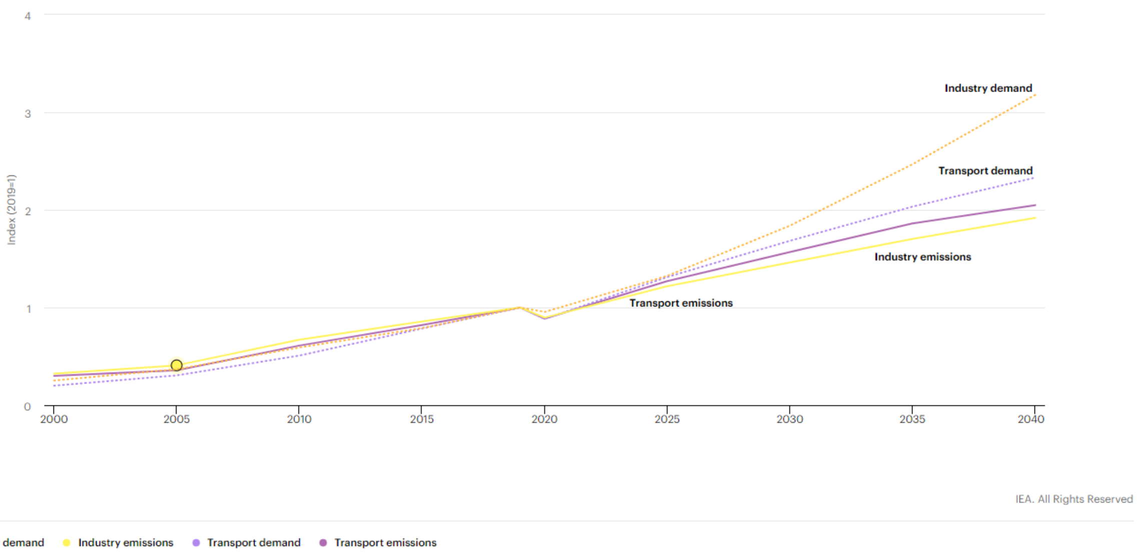

Figure 2: Transportation and Industry Demand forecast, compared to 2019 (Index 2019 = 1). [4]

1.1. Transportation Trends and Economic Linkages

Most people think of transportation as a way to move or carry people and products between two separate locations. This limited vision of the transportation system frequently leads to a misconception of the transportation sector, considering it as infrastructure and limiting its impact to mobility. Therefore, it is important to recalibrate transportation perception, by the figures presented in this chapter.

1.1.1. Transportation and Economy

Figure 3 provides evidence of transportation's role as a link between different economic sectors. It is a key element in the economic cycle. This role is presented in return for a high transportation bill.

Sector	Use of for-hire transport services (US$ billion)	Use of own-account transport services (US$ billion)	Total use of Transport services (US$ billion)	Sector share of total services used
Agriculture	5.720	13.177	18.897	6%
Mining	2.810	3.870	6.680	2%
Construction	13.286	38.950	52.236	17%
Manufacturing	80.248	21.806	102.054	32%
Communications/Utilities	8.803	1.187	9.990	3%
Wholesale/Retail	8.963	42.817	51.782	16%
Services	10.523	42.035	52.558	17%
Finance/Insurance	21.482	0.899	22.381	7%
Total Gross Output	151.835	164.743	316.578	

Figure 3: Industry share of transportation services in 1998, in the United States (US). [1]

Despite their different strategies and modes of transportation, the European Union (EU) and the US present the same trends between transport and economy (see

Figure 4). The increase of Gross Domestic Product (GDP) entails an increase in transport activities of goods and passengers. A mismanaged transport sector, supplemented by an economic growth that exceeds infrastructure capacity, will in turn subdue the full potential of economic growth.

Figure 4: Trends of GDP and Transport Activities between 1970 and 2000 in the EU (Left) and the US (right). [1]

Transportation is tidily linked to the economy. Mobility is measured by the quantity and numbers transported and by the economic impacts behind it.

1.1.2. Transportation's Social implications

Access to transportation is an unknown privilege. The ability to move enlarges the opportunities for correspondent agglomeration. It opens the door for job opportunities, education, health, and other services… This raises the question of "equity" provided by any transportation system. Figure 5 shows the few numbers of transportation inequality worldwide.

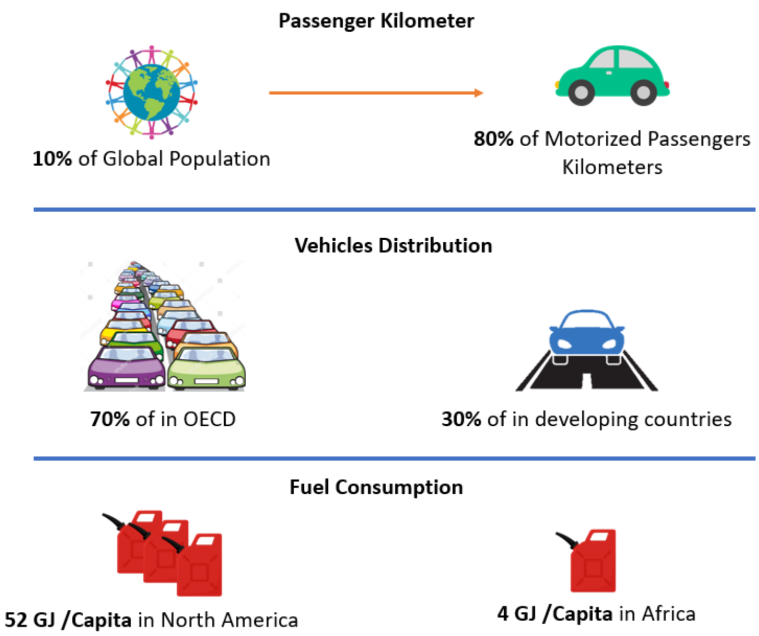

Figure 5: Transportation Social differences. Passenger Kilometers and Fuel Consumption [2]. Vehicles Distribution [3].

1.1.3. Transportation and Sustainability

Transportation is a major energy consumer sector (27,7% of global energy use). Consequently, it accounts for 24% of direct CO2 emissions from fuel combustion (Figure 6) [4]. Road mobility (cars, vans, three-wheelers…) is responsible for three-quarters of total transport's emissions. These facts reveal the intensity of transport's externalities.

Pollution costs, energy security, social equity, economic impacts… are terms to be added to the transportation glossary. Its indirect effects reflect the "importance" of an appropriate transport system. In order to respond to these questions, a mobility assessment has to be done, from a large point of view, and not limited to a number of passenger kilometers. **In other words, it is not only an infrastructure asset, transportation is a combination of a vision, strategy, policies that govern the related infrastructures.**

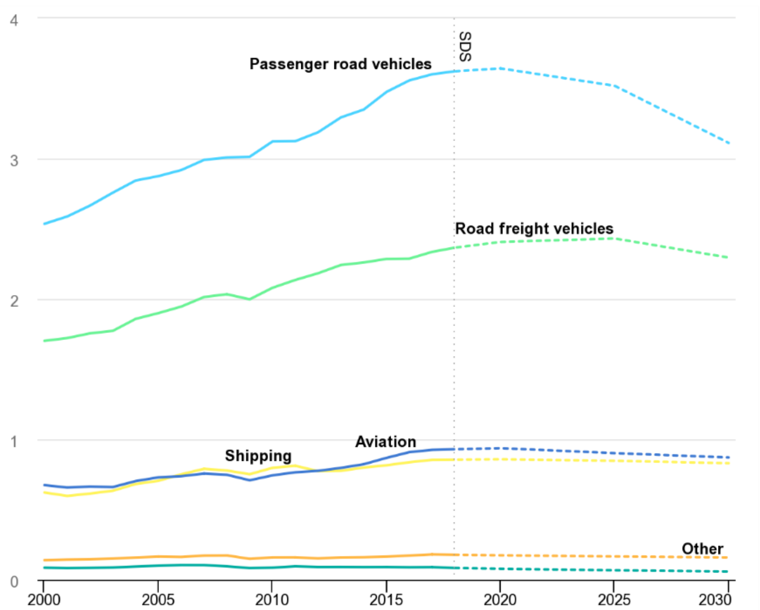

Figure 6: CO2 emissions by mode of transportation (Gt) with the forecast in a sustainable Scenario. [4]

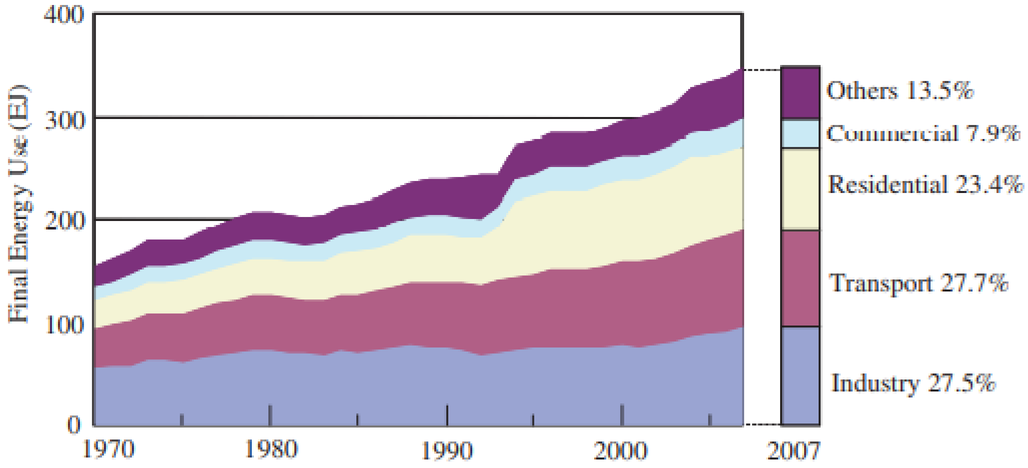

Figure 7: Global Energy use by sectors. [5]

This chapter validates transport's role as the link between economic, social and sustainability.

1.2. Study Objective and Significance

It is expected that 60% of the global population will be living in urban areas by 2030 [6]. This will engender additional pressure on the infrastructure available. With the importance of transport explained above, other tools are needed to provide an efficient mobility system. With a limited ability to provide additional supply, policies are unveiled to manage the demand side. The objectives of this thesis are:

- To define a methodology to assess mobility in urban areas
- To present transportation policies role in mobility systems' governance
- To assess the applicability of a specific transportation policy, a congestion charge, for Lebanon

1.3. Thesis Outline

The content is divided into six chapters, as follows:

- Chapter I: Provides some indicators of transportation and its linkages to economic growth and development and presents an introduction with the thesis goals and outline
- Chapter II: Presents a literature review. The first part tackles the relation between the Sustainable Development Goals (SDGs) and transportation. The second part describes the term urban transportation worldwide and lists key parameters to evaluate mobility in urban areas.
- Chapter III: It discusses the need for transportation policies with example of policies implemented internationally: Congestion charge and low emissions zone.
- Chapter IV: It evaluates urban mobility in Greater Beirut Area (GBA). Then, it simulates the economic feasibility of the proposed project, Beirut Buses Rapid Transit (BBRT). And, it ends by simulating the impact of coupling congestion charge as a policy to the BBRT project.
- Chapter V: A general conclusion shows key findings in the analysis and future work perspectives.

CHAPTER II

URBAN TRANSPORTATION

This chapter is a literature review. It explores the importance of transportation in relation to the United Nations' (UN) Sustainable Development Goals (SDGs). Furthermore, it explains the term 'Urban transportation' and presents a methodology to characterize urban mobility.

2.1. Transportation and Sustainable Development Goals

In 2000, The United Nations (UN) assembly launched the Millennial Development Goals (MDG). One hundred eighty-nine countries supported this initiative to build a more equitable, safer, and prosperous world. The objective was translated into eight measurable goals over fifteen years (ended by 2015) [7]. These goals focused on the "basic needs", poverty, health, economy, environment…. Historically considered infrastructure projects, the transport was not explicitly included in these goals.

As work started, the influence of transportation proved itself as an important factor for development. It directly impacts human rights, environmental problems, and economic development, representing the three pillars for the second phase of development goals, known as Sustainable Development Goals (SDGs). SDGs mention transportation directly as a clear indicator for five goals out of seventeen (Goals:3;7;9;11;12). It is also indirectly tackled in three other goals (Goals: 2;6;13) [8].

Goal 9 aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Indicator 9.1.1, used to assess the work done in this sector, measures "the proportion of the rural population who live within 2 km of an all-season road” [9]. It directly reflects the efficiency and equality of the transportation system.

On the other hand, goal three is looking to ensure healthy lives and promote well-being for all humans. Target nine, under the umbrella of this goal, states: “*by 2030, substantially reduce the number of death and illness from hazardous chemicals and air, water and soil pollution and contamination*” [9]. This time transport is represented by its externality, air pollution.

The relevance of mobility can be seen in its positive impact as an economic stimulator, as well as by its externalities, like congestion and air pollution. This is why other than the above, transport is examined as a contributor to all the different SDGs due to its interactions with the multiple objectives. Indeed, it is not defined as a goal by itself, but it represents a way to all the listed goals.

In addition, SDGs raises an important point, city development and urbanization. Goal 11’s objective is to make cities and human settlements more inclusive, safe resilient and sustainable. This focus is a result of the high urbanization rate worldwide. The UN estimate that **68% of the world population will live in cities** by 2050. Approximately 55% were already habitants of urban agglomerations in 2016 [10]. These high percentages, highlight the fragility of urban transportation to future demand, as it is not possible to reach the announced qualities without sustainable urban mobility.

The next section will cover urban transportation status, problems and present several qualifications parameters.

2.2. Urban Transportation Status

In 2006, one-third of the rural global population, approximatively one billion people, had no access to all weather road and transport services [6]. This limits the ability of these people to access economic and social opportunities. This is a primary reason for migration toward urban areas. Cities are the heart of economic growth. They present several primary services, such as education, health and governmental services, in a smaller area. This makes big agglomerations destination for continuous waves of displacements. This trend accelerates cities sprawling. Area enlargement is proportional to the transport services needed to connect the created suburbs and surrounding. Urbanisation rate is, however, usually higher than the capacity to provide additional and quality efficient transport services [11].

This mismatch of rising demand and supply capacities led to severe consequences. Public transportation remains inaccessible to a big share of cities' populations. Road traffic among pedestrians, cyclists and motorcyclists, acquire 49% of road traffic deaths. The lack of appropriate infrastructure for these modes of transportation is a principal factor of accidents. The consequences of these fatalities and injuries decrease the GDP by 1 to 5%, in developing countries. Transport related air pollution, as well, was diagnosed as the reason for 184,000 premature deaths in 2010 [6].

To be able to tackle the above problematic, a clear definition of urban are must be presented. Urban is an adjective connected to a city or town. It englobes the city centre and all its directly connected area and suburbs. Based on this, Urban transportation deals with all the transportations mode in the correspondent city or agglomeration. It is a part of the urban diagram and itself divided into several subsections. Three components are distinguished [11]:

- Users are the first component of urban mobility. They represent the demand and navigate the travel behaviour.
- Second is the group of various transportation modes disposed to serve the users.
- The infrastructure for transport activity is the third component. It is the total of facilities, model networks and intermodals networks, where mobility services occur.

The group of people affected and affecting the system are an additional component, defining the transport system evolution.

Within all these constraints, SDGs add additional factors for urban transportation to deal with. Sustainable Development as defined by the United Nations (UN), is the ability to seek desired outcomes without compromising the ability of others to achieve their own in space and time [3]. The three pillars of sustainability are economy, social and environment. A sustained transport system must ensure a net positive outcome from the interactions between the three elements. On the economic level, infrastructure costs have to meet the ability of the society tranches to pay. User direct cost, as well, must be adapted to the capacities of the different levels. No burdens must be added on the responsibility of future generations or weak social categories. From the social point of view, all citizens have the equal right to access safe, and secure transportations services. The environmental side deals with the long-term material resources management used and the reduction of mobility environmental externalities. In other words, sustained mobility is characterised by efficient and good quality with the lower externalities possible. The list of externalities is not limited to the environmental effects. Transport creates secondary effects through congestion, noise, accidents, fuel inefficiency, greenhouse gases and others, that will be explained in the next section.

2.2.1. Cities Characteristics

Cities' needs determine the optimal transport system. It intends to serve the metropolitan's user, here is why it is important to understand the correspondent urban context. Urban areas are qualified with an extensive set of parameters. In what related to transport, three parameters describe the urban form and define mobilities patterns [12].

Densities represent the population in certain areas. This parameter gives an initial idea about the need for transportation services and the travel routes. This input is used to assess the needed size of transports modes and the frequency of travel. It can be coupled with activity density which combine people and jobs together. In general, as densities rise, the mobility energy use decline.

Centralisation of Jobs is measured as the percentage of Jobs located in central business district. Combined with densities, it reveals the expected routes for users. In most cities' central business district acquires the majority of jobs opportunities. Thus, it pushes toward a centralised public transit and higher travel distance, considering people commuting from the suburbs. The new urban development admits the necessity to create several centres around the urban sphere and to have an orbital connection between these centres.

Table 1: Urban characteristics in different regions around the world [12].

Region / Countries	Densities *(persons/km^2)*	Centralisation of Job *(%)*
Europe	25 to 80 (Medium Density)	18
US – Canada – Australia	8 to 25 (Low Density)	8.2
East Asia	80 to 300 (High density)	9.1

Table 1 present the different patterns available in different cities around the world. In the US and Canada, cities present a low density, this explains the personal cars dependency in the part of the world. Although, the have also a low centralisation of jobs, but the separation between residential and working areas increase travel distance and push toward the personal cars' choice. In contrary, the European cities are denser and with the high centralisation of jobs percentage. These two factors are the reasons for the prosperity of transit transport and its centralised form in Europe. Big Asian metropolitan are highly dense, leading to a high need of transportation with its related externalities.

The figures of today, are the results of transport modes trying to adapt with the existing urban planning choice in each country. This shows the importance of tackling transportation at early stage to ensure an efficient sector.

Wealth is the third parameter. It is measured with GDP per capita. The influence of wealth can be in both directions depending on the user perspective. It can be used to buy bigger house outside the city as the trend in the American countries, and increase the demand on suburbs connections. And it can be used as well to buy a central apartment near the different facilities, with no need for motorised transport services.

2.3. Externalities

Externalities are the impacts that any transport service causes. There are methods to monetise or internalize the impacts, direct and indirect, of this service/transport done on other persons or on the environment. By this definition, externalities do not affect the user choice of transport mode. Generally, these costs can be covered directly or indirectly by the government, through collective taxes. It is hard to estimate the indirect costs of mobility due to the difficulty to determine the precise space, time and value of the effect itself. On the way there, external costs are classified under the following categories [13].

Accidents Costs cover the different bills resulting from costs. To stay within the definition, all points covered by the insurance (ex: Car repair) is not considered here as it will be paid by the user. As it is directly linked to damage caused, it is well developed into five components:

- *Human Costs*, it estimates victims, other than the user, suffers and pain resulting from the accident.
- *Medical Costs*. This component covers the victim medical treatment, appliances and medicine over the full recovery period, excluding those covered by insurance.
- *Administrative Costs* covers the different expenses for all the institutions that provide any kind of support during the whole accident resolution process (firefighting, police, justice…)
- *Production Losses* accounts for productivity loss and reduced victims working time due to the accident injuries.
- *Material damages* englobes all the costs for material repairs, in vehicles, infrastructures or any other assets.
- *Others costs* is the sum of all the residual damages costs such as vehicle unavailability.

Air Pollution Costs are the result of transport pollutants' negative impacts. It is the most analysed externalities. Damages is not limits to the human health effects, it reaches also materials and building, crops and biodiversity. Pollutants' inhalation leads to a high risk of respiratory problems. The resulting consequences are monetised in this category. Crop losses and damaged yield are also consequences of transport pollutants, specifically ozone. Also, higher pollutants' concentration perturbs biodiversity and ecosystem (ex: acidification of soil). These damages costs fall under this category.

Climate change Costs take into consideration the long-term effect of transport emissions. Green House Gases (GHG) gases emitted by transportation modes, contribute to climate change. Direct and indirect emissions (emissions from electricity generation for tram supply) are assessed in this part. And in its turn, climate change results in extreme weather, higher temperature, higher sea level… Climate change external costs are hard to estimate as they reflect long-term effect.

Noise Costs, as shown by their name, estimate the impacts of mobility resulting noise. Noise is defined as unwanted sounds of varying duration and intensity. Traffic generates noise at different levels. The exposure to the unwanted sounds results in several health problems (ex: stroke, dementia). Noise costs estimate the value of these health issues.

Congestion Costs represent the losses value, due to time delay. Congestion is the impedance of cars on each other, where traffic approach the maximum capacity of the road. This impedance creates a domino effect, reduce speed, and by consequence increase travel time.

Cost of well to tank emissions reflect the residual cost of energy sources extraction/production, that is not paid by the end-user. The cost covers the different negatives impacts of downstream process.

There is no harmonisation of external costs. Therefore, other categories can be seen such as ***Habitat damage cost***. All externalities not included in the above categories can be grouped in other externals costs. The resulting value of externalities calculation reveal the true cost of mobility, and the small amount borne by the user. Or to correct the payment balance, different tools can be applied. This part will be discussed in the next chapter.

2.4. Urban Transport Monitoring

Several factors are developed to assess the efficiency of transportation system. Performance assessment is essential for future development plan. Assessments can be done separately to private and to public transportation. This section will present few factors that can monitor transportation services' performance [12] [14].

2.4.1. Demand:

First step to evaluate the performance of Transportation, is to assess the need for mobility services, ***Transport Demand***. There are a lot difficulties to estimate the need for transportation, owing to the fact that non-motorised trips are not measured and are difficult to estimate. To have an approximate idea about the need, the total *Passenger Kilometres (Pkm)* is used as an indicator. It is the sum of the total Pkm for the different modes of transport.

Using this indicator, the ***effectiveness*** of any transport mode could be seen as the ratio between *Passenger Kilometres per ton of kilometres* ***(Pkm/Tkm)*** served by the correspondent mode. This factor presents the importance of public transportation, as their occupancy rate is much higher than private cars, therefore present higher effectiveness for a similar trip.

Still, from the user point of view, effectiveness is not his concern. User selects his transport mode based on service quality.

2.4.2. Private Cars:

For private cars, service is directly linked to four main factors:

Car Ownership. It reflects the vehicular stock available in the city. It is presented by number of cars per 1000 persons. Several conclusions are retrieved by this value. It reflects the car mass on the roads and its impact on the overall service. It also indicates the dependency on private vehicles. High car ownership is a result of a high dependency on private automobile. It also gives an idea on the regulation level (strict – Open) for cars acquisition. In Singapore, extremely expensive car purchase costs limit the ownership at 100 per 1000 persons in 2005, same in Hong Kong with even lower values at 57. On the contrary, in more private vehicles open countries US and Australia, figures are much higher at 647 vehicles per persons at the same year [12]. (See Table 2).

Freeway supply. Freeway are highways designed free from traffic signal, intersections… to ensure fast speed travel. Supply is evaluated by freeway length evaluate per persons. Similar to car ownership, this factor reflects the transportation policies applied in the correspondent country. Same trend is followed here, Asian cities present the lowest highway supply, at 0.025 m per persons, Europe is in the middle at 0.08 m per person. And North Americas countries present the highest value at 0.156 m per person [12].

Parking supply. Parking availability determine the attractiveness of car for commuting. The availability is estimated by the number of parking space per 1000 workers in the same area. The trend is to decrease parking space worldwide. This is driven by the resulting advantages, larger pedestrians, cycling and green areas.

Car Use. It is measured through the value of annual car passenger kilometres per person. Car is highly used in US and Canadian cities, European are on average, and Asian cities are the least car dependant.

Table 2: Private transportation figures in 2005 [12].

Region / Countries	Car Ownerships *(car / 1000 persons)*	Freeway Supply *(m / person)*	Parking Supply *(Parking spaces /1000 workers)*	Car Use *(Car Pkm per person)*
US – Canada – Australia	604	0.132	1104	13,215
Europe	412	0.080	212	6,319
East Asia	73	0.025	135	1,978

2.4.3. Public Transportation:

For public transport services, analogue factors are defined, to determine the attractiveness of this mode:

Reserved transit route per person. Speed is essential in mobility, and for public services, dedicated lane is one measure to provide fast public transport. The number of transit lane length per capita. This factor reflects the speed of public transport. Total length is increasing internationally. In opposition to the expected, Asian cities have the lowest length per persons, within the three categories (See Table 3). This is the consequence of their huge population. Europe leads on this factor followed by American system.

Public transport seat kilometres per person. Another factor to assess the service is the availability of seats on public transport modes. The supply is measured by the number of total annual seat-kilometres per person. Globally the public transportation supply is increasing, in order to respond to the high demand. In contrast, to the private transportation figures, for public services are dominant in Asian cities, Europe again in the middle and North Americans cities provide the lower rate of public transport.

Total annual public transportation passenger kilometres per person. It indicates the use of public services by people. It is the annual travel distance per capita. Again, this factor combined with the seat kilometres per person, confirms the leadership of Asian cities in the public transport services, followed by European cities.

Table 3: Public Transportation figures in 2005 [12].

Region / Countries	Dedicated route length (km / person)	Supply (Seat-km / person)	Use of Public transportation (Pkm per person)
US – Canada – Australia	100	2,773	892
Europe	231	6,126	2,234
East Asia	18	7,267	3,786

2.4.4. Comparison Indicators:

In addition to the evaluation of the two branches of transportation, there are also additional factors to compare between private and public mobility:

Ratio of Public Transit speed to road traffic speed. The purpose of mobility is to change location. Or time needed to achieve this goal is highly important, and is directly linked to the mode speed. That is why this ratio reflects the faster mode between both public and private transportation modes. As its name indicates it is the ratio of overall public modes by the average car speed in the city.

Share of different modes. It is the ratio of Pkm for a mode of transportation over the total Pkm demand. This indicates the share of each mode of transportation.

Energy Use. It can be calculated separately to the private and public transport, in *megajoules per person*. It is the total amount of energy used by the number of persons served. Public transport is less energy intensive than the private one. Still energy consumption is decreasing for all type of transport.

Table 4: Transportation Comparison Figures in 2005 [12].

Region / Countries	Speed Ratio *(Public /Private)*	Public Transport share *(%)*	Public Transport Energy Use *(MJ /Person)*	Private Transport Energy Use *(MJ / Person)*
US – Canada – Australia	0.63	7.5	1072	40,072
Europe	0.88	24.5	1,532	15,795
East Asia	0.86	62.9	2,691	6,076

Case Study: Brazil, Turkey, Iran [42]

Transport in developing countries is regarded as a secondary sector. In addition, It is hard to monitor this sector due to the lack of data. This box presents some figures from developing countries similar to Lebanon, to have an overview about transport situation in similar countries.

Country	Brazil	Turkey	Iran
Urban Population (%)	85	73	70
Car Ownership (per 1000 persons)	200	176	250
Public Transport Share (%)	30	60	41
Cyclist Pedestrians conditions	Medium	Medium	Poor
Challenges	-Lack of support for NMT* -Security in PT* -High PT fees -Lack of Urban planning in the suburbs -No clear responsibilities	-Low PT supply -Congestion -Lack of legislative framework	-Low PT speed -Low PT supply -High Congestion -Decision Making fragmentation -Corruption in planning process

*NMT: Non-Motorized Transport / PT: Public Transport.

The common problem for developing countries is the master planning of transport, including all modes of mobility. It is clear the NMT are neglected and no proper infrastructure are provided for walking and cycling. The only public transportation attractiveness is its lower cost. It is qualified by its low supply and low speed. The increase of income level usually leads to the transfer toward private cars.
This is due to the fact that there are no clear regulative and planning governmental body responsible for transportation planning.

CHAPTER III

TRANSPORTATION POLICIES

This chapter discusses transportation policies, as a solution for urban mobility challenges presented in the previous chapter.

3.1. Transportation Planning

The previous chapter explained the importance of urban transportation and presented the constraint to develop a sustainable sector. From here, Planning, specifically transport planning is essential to find the optimum development of the sector. In other words, planning is the way decision-makers design and implement urban transportation strategies to achieve desired outcomes [11].

When speaking about transportation, chosen strategy must be based on three interconnected elements management. First, ***supply management*** deals with the construction of new infrastructures or adoption of new modes of transportation. Supply is in a continuous feedback loop with the ***demand management***, the second element. Demand is functions of several factors (job creation, demographic evolution, services…). However, there is a set of soft tools to manipulate the demand side, it relies mainly on policies tackling consumer behaviour, trying to shift toward the optimum scenario. ***Land use***, the third element, influence both supply and demand and limit the ability of adaptation, mainly in cities. Spatial distribution affects transport mode selecting behaviour, for example it can eliminate non-Motorised transport, due to inaccessibility and disruption of cycling lanes or sidewalks. Likewise, in case of saturated road, in a narrow street, new roads construction is impossible.

These three pillars are governed by an evolving environment. The key factors for this environment are the change in society, change in technology, change in policies context, and change in institutional framework.

3.1.1 Strategic Planning

Traditional Transport Planning was based on the approach "predict and provide". In contrast, Strategic planning aims to control the three pillars cited above. The methodology followed should acquire important features: orientation toward sustainability, integration of different stakeholders, and systematic approach based on performance evaluation. Strategic planning process is simplified into the following phases [11]:

A. *Set a Vision*: A clear vision of the urban area 's future is the start point of transport planning. Usually, the vision is set at the political level.

B. *Diagnosis*: It consists of the assessment of the environment and the different alternatives available on the decision maker's table. SWOT (Strength, Weakness, Opportunities, and Treats) and PEST (Political, Economic, Social and Technological) analysis are two tools used for the assessment at this level.

C. *Design:* Following the outcomes of phase two, decision makers select the adequate transport solution. Some space for relevant stakeholders is essential for a smooth and quick continuation of the process. The design defines the process and activities for solution implementation, to achieve expected outcomes.

D. *Implementation, Monitoring and Evaluation:* the designed plan then passes to the implementation phase. All along the phase Monitoring and Evaluation are essential. It helps detect and evaluate any distortion of the set goals. Evaluation outcomes improves both strategic planning process and adopted solution adaptation.

Solutions, in planning context can be physical (new mode of transportation) or soft solution, like Transportation policies, that are tackled in the next section of this chapter.

3.2. Transportation Policies

This Section is mainly based on the World Bank guideline, “Formulating an Urban Transport Policy” [15], otherwise reference is indicated.

3.2.1. What is a Transportation Policy

Transportation policies (TP) are the framework formulated in order to reach the objectives set by the government to improve the transport sector. They enunciate the direction and guidelines for the transportation Action Plan (the batch of interventions to be done), see Figure 8. Due to the different in environment, conditions and objectives, there are no ultimate TP applicable worldwide. TP must be modelled to respond for each country, governorate or even city level case.

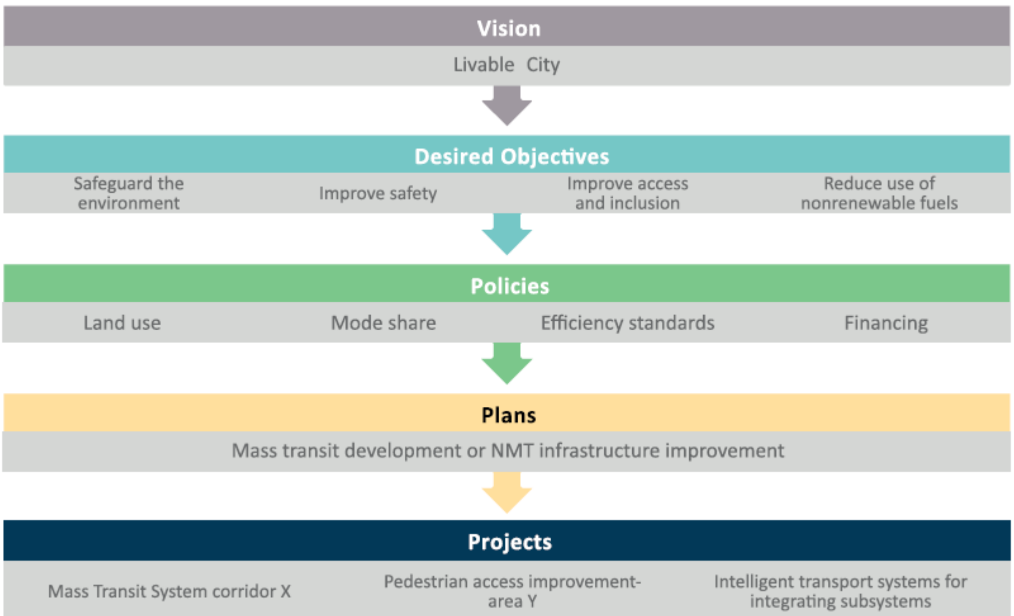

Figure 8: TP position within the planning chain [15].

3.2.2. Why do we need Transport Policies

Development of transportation is not as easy as to deploy additional vehicles or to construct new roads… The triple convergence principals are the first evidence for the need of TP.

Example: A new road is established. More people will use their cars, with an additional space created (spatial convergence). Additional group will use the new road at peak hour, with new space in mind (time convergence). Even some will shift from public transportation to their own cars, due to the low congestion on the new road (modal convergence). The three convergences will lead to a quick annihilation of the new road capacity, leading back to the starting point. The principal can be applied for other mode of transportation, as well. Here comes the importance of good governance, led by adequate TP. This governance tries to guide the market and *create an equilibrium between supply and demand.*

Add to the above transport externalities discussed in chapter three, and the continuous efforts by governments to minimise their effects, without compromising the availability of transport. This availability is measured by affordability, accessibility and quality. *TP are the tools to optimize transport in order to lower externalities and respond to mobility demand.* The goals of TP can be summarized as, the interference of government due to [16]: Market Failure (Market Governance), Equity Reasons (Transport Availability) and Generating revenues (one of the public Transport financing streams)**.**

3.2.3. What are the different types and targets of Transportation Policies

As mentioned in previous sections, Transportation is midway of different sector and the veins of the economic development. *TP can be categorized into 5 types:*

Economic, Information, Technology, Regulatory, Planning. All types are categorised within three targets tackling the transport planning pillars: Demand and supply management and Land use [17]. Below are some examples of the different types of TP, with several targets.

Land Use. Urban growth increases the pressure on the transport systems and generate more externalities. Controlling and guiding this growth, although challenging, help relieve several problems. Two inputs parameters are needed to describe this growth and manage it, growth projection and availability of Land. The three mains' instruments, to channel the growth on the optimum track, are:

- Densification is to give the permit to a more intensive use of Land. This can be achieved by a higher floor are ratio (higher number of floors) and higher limits for holding. These actions lead to a more compact city, with short distance to be travelled, and encourage motor-vehicles replacement.
- Mixed Land Use allows living and working locations to be dispersed in the same area. In results, daily trip length and reliance on cars is decreased.
- Defining boundaries will limit the urban growth to a certain area. This policy can help relaxing public transportation systems and avoid over demand. Plus, it encourages the development of adjacent compacts urban centers instead of one mega pole.

Demand Side Management. There are several means of transportation available classified under two categories: motorized (public and personal) and non-motorized. Each mode has its characteristics (pollution, energy consumed, operating costs…). The attractiveness varies according to the environment or conditions. Often the individual choice of transport mode is not in accordance with the public interest. As people tend to use cars instead of public transportation. To break this tendency promoting several modes is used. The first step for the authority is to chooses the adequate mode for the concerned area of studies. Then applies measures to shift the population use toward the mode chosen. The measures can be:

- To Ensure privileges such the right of way for certain modes (bicycles lanes)
- To provide incentives, making a mode more profitable or economic viable
- To add fees on other modes, making it inconvenient to use. Congestion Charge is an example of taxing private motor vehicles in peak hours. It will be discussed later in this paper.

Supply Management. To provide effective transport system, the operation modes and fleet must meet the needs of the agglomeration. Accordingly, authorities must deliver additional capacity for transportation where needed. Supply policies select the optimum mode of transportation to adopt within a concerned area. In addition, they determine the financing mode The general trend is to increase in capacities of public transportation means and other efficient modes. This is done by supplying new buses and enlarge the fleet, to extend cycling line and sidewalks… The important point for decision makers is to properly address the two sides, demand and supply, with a combination of coordinated measures.

3.2.4. How to develop TP

Multi-Level. Transport must be addressed on different levels. Strategic Plans and future goals (long term objectives 15 to 20 years) must be defined for a vast area (agglomeration), thus at the level of country or state government. Governments are responsible for transport standards, regulatory laws, long term investment… High level institution planning, is important to avoid disrupting the sector. A city cannot enforce electric cars for example, independently than the surrounding area. City inhabitants will not be able to use their cars outside of the city, because there is lack of electric charging stations. Other citizens also cannot enter the city due to their motor-vehicles. All the territory must move at the same pace. Governmental authorities are responsible to ensure an efficient transportation network, connecting its different nodes and cities, designing roads, financing projects... This can englobe investment planning and project with a horizon of 10 years. City or municipality level also have several roles such as, operation of services, capacity buildings, enforcement of regulations… these levels can vary based on the size of a city or a governorate. The main point in TP is to have shared functions across multiple levels.

Institutions. Transport is a midway between several sector, hence different agencies. It encompasses several dimensions legal, public works, urban development… The input of each agency depends on the urbanisation stage. At city planning, urban planning is more involves than the management of transportation experts. Or when cities are built and minor planning action can be taken, the major role is transferred to the transportation management. Therefore, it is essential to have a lead agency. The lead agency must bear in its scope of work the different aspect of transportation, planning, construction, transportation management or it can be the link between the related stakeholders. Coordination is a must. Parking regulations should be in coordination with transit policies because transportation is a chain of actions that affect each other. Furthermore, the Lead agency must be granted the needed power in order to fulfil its functions.

Strategies. Officials must determine the future strategy of transportation. The strategy defines the set of goals, under the three planning pillars.

In summary, Policies must be based on a clear roadmap set at different level, integrating all stakeholders.

3.2.5. The path of a TP

Drafting. An expert or a community present an initial draft for TP. The draft must be readable, easy to understand by different level of decision makers. The draft has to be clear, simple, short to medium length, and supported scientific evidence. Two additional important qualities "Practical and Doable".

Consultation. This phase seeks to improve the draft based on suggestions and comments, to discuss the choices made, convince a wide audience and to win stakeholders' support. Consultation can be made in several seminars, workshops, meetings… Work with the press is essential to build public support as well [18].

Refinement. It is the transformation of the draft to a final document based on the consultation results.

Implementation. It is made on several segments. Step one, to enact Policies Form. The form can vary between legal aspect (decree or legislation), and non-legal. Non legal document can specify incentives and action to be done or statement of the objective only. Step two, is to enforce, apply and supervise the policies measures. An effective institutional mechanism must be in place. The lead institution is the main agent again. Final step, consist of capacity building. A well-trained team, and an adequate supporting system (database, financial resources, support systems…) are key element for good implementation. *A good policy is a well implemented policy.*

3.2.6. Transportation Policies' challenges

Table 5 presents transport policies' mains challenges.

Table 5: Transportation Policies main challenges.

Transportation Policies Challenges
1. Good Planning, through accurate projections based on scientific values
2. Robust and efficient governing system
3. Rely and complement the existing situation
4. Clear definition of the influence radius and targeted population
5. Balance the supply and demand side
6. Balance the policy's positive and negative impacts
7. Ensure reliable financing (by users, beneficiaries, or private and public sector)

3.3. Congestion Charge

3.3.1. Principle

Congestion is a worldwide city challenge. It is the results of personal vehicle growth versus a limited road capacity. This imbalance between demand (numbers of cars) and supply (road space) is revealed at peak hours. Congestion lengthens trip's journey, increases energy consumption, pollution and traffic accidents.

With the limited ability of supply of new roads inside the cities, countries have turned to find solutions based on demand side modifications. A widespread and effective measure is congestion charge. *It is a fare imposed on motor-vehicles on certain roads (mainly inside cities) at certain time (most likely peak hours).* This policy date back to 1920 when proposed by Pigou [19].

Moreover, Congestion Charge goals can be as follow based on the need of the city of implementation:

- Manage transportation supply and demand

- Enhance the transportation system in the city (adjust travel time and increase average speed)
- Lower pollution level and energy consumption.
- recover transport externalities during congestion, which will remain unpaid otherwise [17]
- Diversify transport modes by pushing toward non-motorized or public transport modes.

3.3.2. Application:

Congestion charge (CC) is defined by its three components: fares, roads where to be implemented, and the method of detection.

Fares. The difficult task, in congesting Charge, is to determine the right fare to impose. In theory, it should be equal to the externalities of transport. Being hard to monetize, congestion fare must be set based on the following guidelines [19]:

- Public transit or high occupancy vehicles (vans, buses) must be excluded from charges or less charged, to ensure the shift from personal cars to collective modes.
- Variation of the charge based on the degree and duration of congestion, higher charges for the most congest sections of the roads, while road with short congestion should be charged lower. This will deviate the route selected by travellers toward the non-congested one.
- Charged roads must rise the total journey cost to exceed other paths via the road network. Otherwise, users will always choose the most feasible solutions and there will not be a reduction of flow.
- Most important is to have a rational charge compared to the traveller’s ability to pay, or else it will be publicly rejected and unable to implement.

Scope. There are two main types of Charge scope:

- Regional charge implemented overall a specified area. Charges are applied to cars entering and within the area.
- Bottleneck Road charge applied on the entrance of the cities for examples or the key intersections. This can be applied in one or both direction (example: entering and exiting the city).

Method. There are two method of implementation, manual and electron charge. Manual is done via official's persons recording violations. This system is less efficient, because enforcement is done randomly, presenting a lower detection rate. The electron method consists of electronic equipment fixed at the charging scope and can detect cars plate or another paid label and detect violating one.

3.3.3. Criticism:

Congestion Charge presents many advantages and tackles several transport negatives effects at the same time. Still the major criticism for Congestion Charge is the effect on low-income inhabitants, because they cannot afford the fees applied. Thus, it violates equity between social categories. A case study for Stockholm, showed that there is a trade of between efficiency and equity in congestion charge design. Developing the most effective design will results in, high incomes group gains most from congestion charge, and low income gain least [20].

Case Study: Congestion Charge in London [43]

The charge covers a 21 km^2 area at the heart of Central London, limited by the inner ring road. A £5 fees was originally assigned and rise since then to 10£. Charging applies from Monday to Friday from 7:00 am to 6:30 pm. Residents of the area are excluded. All motor vehicles are subject to the charge except motorcycles, public duty or emergency vehicles… Renewable fuel cars are also exempt from paying the charge, to encourage the shift toward sustainable transportation.

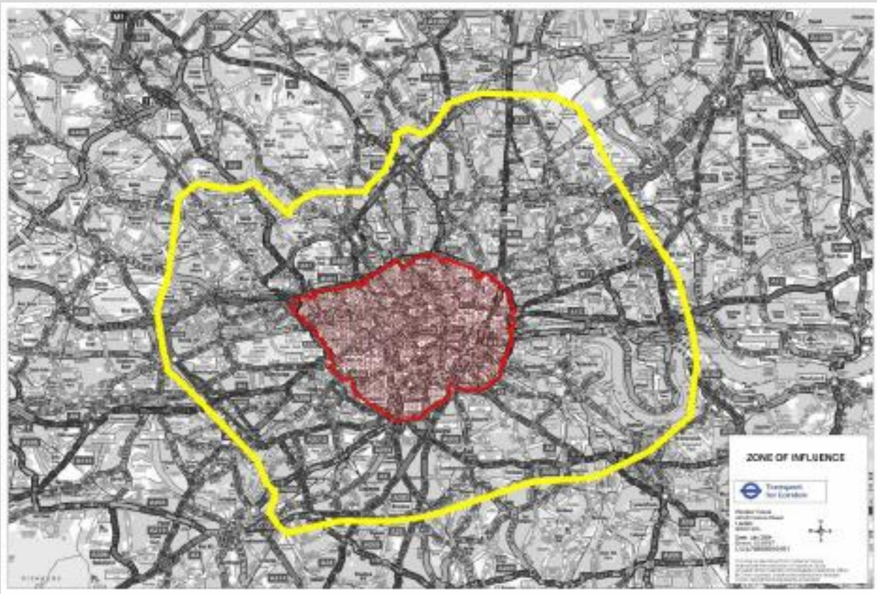

Figure 9:Congestion Charging Area (red) plus Zone of influence (Yellow boundaries) in London.

Impacts	- Daily traffic Reduction by 44%. - Increase numbers of cyclers, public buses and Taxis - 181 million GBP Revenues in 2012-2013 - Air pollutants Reduction (-8% NOx and -16% CO_2) - Reductions of accidents
Key Elements	- Political Commitment - Scientific Plan - Public engagement - The supply of good alternatives - Effective Traffic Management - Continuous Development

3.4. Low Emissions Zones – Emissions Charges

3.4.1. Principe

Several countries struggle with high concentrations of particles and nitrogen dioxide (NO_2). Road traffic is an essential contributor to urban air pollution. In Germany, road transport is estimated to account 60% of NO_2 concentration, compared to 65% in France. Indirect health costs of road air pollution are estimated by 67 to 80 billion Euros annually, based on the European Public Health Alliance [21] [22].

In this context, Low Emissions Zones (LEZ) emerged as a solution for air pollution. LEZ is a defined area where access for the most polluting vehicles is regulated, either by forbidding the most polluting to enter the zone or by demanding a fee for the polluting vehicles to enter or drive in the zone.

The main goal of LEZ can be concentrated on the air pollution reduction, but still other benefits were sought by the implementation of this policy like:

- Faster upgrade of the vehicles fleet
- Reduce Traffic in the correspondent area
- Transport modal shift toward public transportation and non-motorised transport
- Reduce noise level (Usually newer vehicles generate less noise)

Sweden was the first European country to implement LEZ in 1990, and due to its success, there are today more than 260 different LEZ in the Europe.

3.4.2. Application:

The effectiveness of LEZ highly relies on its ability to change in the composition of the vehicle's fleet. Therefore, several key variables can impact this ability, same as seen in the case of congestion charge:

- Territory covered: The size of LEZ is the main factor, because it defines the impacted population and the vehicles fleet concerned.
- Level of Stringency: The more restrict are the regulation, the more effective. Still, additional restrictions englobe a wide share of the population and raise the question of social equity and decrease the compliance rate.
- Exemptions: Certain users require exemption for specific reasons. Common exempted categories are emergency response vehicles, military vehicles, veteran vehicles, and disabled persons vehicles. This list can be adapted based on the local context. Still A higher number of exemptions can dilute the policy effects. In Berlin, exemptions are capped at 10% [22].
- Clarity: the policy should be enacted in a clear timeframe, for users to adapt their behaviour on the long term.
- Fees and fines: The applied fees/fines should be well designed, to push the population toward compliance and in the same time providing social equity.

3.4.3. Criticism:

Similar to Congestion charge, the social equity question is also raised for LEZ. The attitude toward LEZ, however, is less severe. Poor population are the most exposed to air pollution, and the least likely to own a car. For this reason, generally, citizens support LEZ. A survey in nine European countries showed that 67% are in favour of LEZ implementation.

LEZ proper design remains an essential factor to address social concerns.

Case Study: Low Emissions Zone [22]

Country	Sweden	United Kingdom (UK)
Starting year	1992	2008
Level of Governance	National Authority (Trafikforoodning) With possibility of local adaptation by municipalities	Local at the municipality level
LEZ Regulations type	Three possibilities available on the national level local municipalities choose the appropriate solution: - LEZ 1: only for Heavy Duty Vehicles - LEZ 2: including cars, minibuses and vans, following Euro 5 and Euro 6 - LEZ 3: only allow low emissions vehicles to enter the zone (e.g., electric, hybrid)	In London starting from 2012: Minimum od Euro IV for Heavy Duty vehicles, and Euro III for vans, minibuses. Other cities adopt Euro III and Euro IV
Cities	8 cities, mainly Stockholm, Malmo, and Gotenburg	5 cities, most importantly in London
Enforcement	Random Inspection from traffic police	Cameras and automatic Number Plate recognition
Fees / Fine	107 euros fine for non-compliance	Variable entering fees based on vehicle types 118 euros for vans 236 euros for Heavy duty vehicles
Results	Average age of buses reduced 40% reduction of PM emissions* 10% reduction of NOx emissions (Year 2000)	Increase the rate of fleet turnover 3.07% reduction of PM emissions No difference for NOx (Year 2011)

*PM: Particulate Matter

CHAPTER IV

LEBANON CASE STUDY

This chapter evaluates the applicability of transport policies in Lebanon, with more in depth on Congestion charge and Beirut Buses Rapid Transit (BBRT) coupling.

4.1. Current Situation

Lebanese infrastructure is basically the remaining of the Ottoman Empire and French mandate era, along with two period of development in the 1960's and 1990's. Actually, Lebanon presents an incomplete network of road lines based on the centre periphery model, and the network is mainly concentrated by the T-section of the two major roads Tripoli-Tyre and Beirut –Damascus [23]. Approximately 30% of roads are classified under the authority of the Ministry of Public Works and Transportation. Approximately 17% of the classified network are in good conditions, and 70% are in fair condition, while the rest of the network condition varies from poor to critical [24]. Public transportation is almost absent in Lebanon, although a total of 6,200 buses, 14,000 minivan and 52,000 taxis are available (high supply) but working randomly with a low service quality, thus not offering an appropriate service [25].

4.1.1. Important Figures

Fuel Consumption. Transport sector is second largest energy consumer, only after power generation. Road transport relies mostly on gasoline and gas diesel oil, as fuel. In 2015, fuel consumption was estimated at 521,000 tonnes of gas diesel oil and 1,905,000 tonnes of gasoline [26]. This number represented 31% of the national primary energy consumption.

Emissions. Based on the third biennial report to the UNFCCC 2019 [26], transport accounted to 6,146 Gg of CO_2 equivalent. In term of percentage, it represents 26.7% of the energy sector emissions, and 23% of the national GHG emissions. Passenger cars are the primary emitting source in road transport with a share up to 57%. Moreover, Transport is also responsible for 61% of NOx emissions and 99% of CO emissions in 2013.

Vehicle Fleet. The Lebanese fleet is dominated by passenger cars (private vehicles), making up to 57% of the total registered vehicles. Due to the lack of public transportation, private cars increased at rate of 3% between 2010 and 2015 [26]. They reached 1.45 million cars (222 cars per 1000 inhabitants, compared to 569 in the EU). If following the same trend, the number of passengers cars will reach 1.85 million cars by 2025.

4.1.2. Greater Beirut Area

The major focal point of transportation is Greater Beirut Area (GBA). It is the region extending from Naher el kalb from the north to Naher el Damour south. GBA account 40% of the Lebanese Population, with 1.5 million daily passengers [27]. In times, there were railway connecting Beirut to the south, north, and east of Lebanon. The railway network has been completely abandoned in 1995. Inside Beirut, four lines of tramways used to connect its different parts, all passing by the martyr square as a central point. Tramway also stopped in 1965 due to the lack of urban planning and modernization [23].

With the lack of Public Transportation means, private vehicles remain the primary transportation solution in Lebanon. Daily traffic on Northern Beirut entrance is estimated by 300,000 cars, 200,000 and 150,000 on the southern and eastern entrance respectively [25], with an occupancy rate of 1.2 per car which is very low and an average trip distance of 9.3 km (short trip) [27]. Private cars account for over 80% of circulating vehicles in GBA. These huge numbers of congestion led to huge negative consequences:

- A peak speed of 30 km/h on highways and 10km/h on local streets [25].
- 5 to 30 min of delays per trip [27]
- 2.7 times more of gasoline consumption compared to neighbours' countries [27]
- Stop time account more than 15% of travel time [28]
- Need for additional road space
- Need for additional parking space
- High transportation cost (15% of total household expenditure) [25].

These high numbers emerge the need to restructure the transportation sector. They cannot be achieved without the search for adequate policies for a well governance.

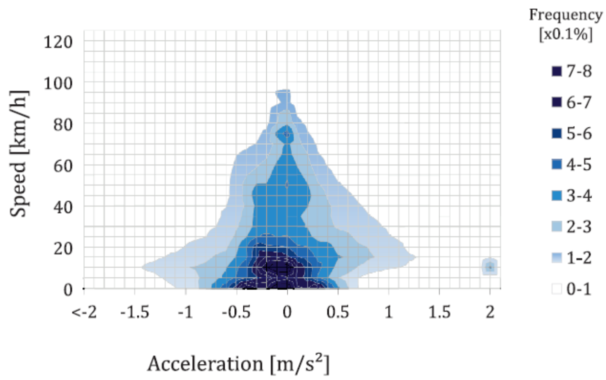

Figure 10: Speed - Acceleration frequency distribution in Greater Beirut Area.

To measure the intensity of urban transportation problem in GBA, the parameters introduced in Chapter 3 are evaluated.

Table 6 presents the city characteristics for GBA. Due to data scarcity, jobs centralisation was calculated compared to jobs in all the Lebanese territory. It is the ratio of number of employed people in Beirut/GBA to the total number of employed people in

Lebanon, using the data retrieved from Labour force and household living in Lebanon 2018-2019 [29]. The number of employed people take into consideration only the people residing and working in Beirut, thus the real value is higher, because many people from outside Beirut works within the district zone. In the case of GBA, number of employed people in Mount Lebanon districts is calculated based on a uniform distribution of employment on Mont Lebanon’s area. Still the value presented is a good start point to assess the urban mobility in GBA.

Table 6: GBA city characteristics.

	Greater Beirut Area	Beirut District	European cities [12]
GDP per Capita *(USD)**	7,645		30,474
Population density** *(persons per km^2)*	8,695		25 to 80
Jobs Centralisation** *(%)*	>10%	>8%	18%

**World Bank Database*
***Based on Calculations*

The values for the urban transportation parameters in GBA, presented in Table 7, were calculated as follow:

- Freeway supply is based on GBA maps analysis. the total length of freeway was retrieved from public maps. There are 89 km of freeway in GBA, mainly the three entrances freeway and big part of the outer ring. The total length was divided by the population of GBA.
- Parking supply was extrapolated from a previous study done at the American University of Beirut (AUB) [30]. The study finds that there were 1785 parkins

space in the studied area in Hamra (0.16 km^2). After extracting specific area, (like the port and Hourch Beirut), a rule of thumb was applied to find the number of parking spaces in Beirut. Number of workers used is the same as in the city characteristic part above.

- Car use is calculated as the ratio of annual travelled distance of cars by the occupancy rate [27].
- Public transportation use is the average of taxi, vans and buses use. PT use is calculated in the same manner as for private cars [31] [32].
- Transport demand is the product of daily passengers' number and the average trip distance.

Table 7: Urban Transportation characteristic in GBA.

Parameter	Value
Car Ownership *(Number of cars per 1000 inhabitant)*	222
Freeway supply *(m / persons)*	0.045
Parking Supply *(Parking space per 1000 workers)*	<1377
Car Use *(Pkm per person)*	10,000
Public Transportation *(Pkm per person)*	5,416
Reserved Transit route per person *(km)*	0
Transport Demand in GBA *(Million Pkm per day)*	14
Modal share *(%)*	10% buses 19% Taxis/services 71% private cars

Table 8: Analysis of the GBA parameters.

Analysis	Conclusion
Jobs are centralised in Beirut districts, which create a high flow of passenger movement within the GBA, less than 10 km → **short trip distance**	Need for Public Transportation
On the national level, jobs centralisation in GBA, leads also to a passenger flow from the rest of the Lebanese territory to GBA, putting pressure on the northern, eastern and southern entrances.	Adequate National Transportation Plan
High density reflects **the need for high occupancy rate in transportation**, to ensure balance with the limited infrastructure available	Need for Public Transportation
Cheap transport mode is needed to align with the low GDP and ensure social equity	Need for Public Transportation
No transit route and limited freeway and parking supply, represent the **poor transport infrastructure** for both public and private modes	Need for infrastructure rehabilitation and supply
People are relying on private cars, due to the **lack of infrastructure and appropriate solutions**. This results in higher car use.	Need for alternatives Need for Public Transportation
Low occupancy rate of public transportation, despite the high supply (private operators) reflects **the market** equilibrium	**Need for governing policies**

4.1.3. Road Transport Externalities in Lebanon

As explained in Chapter 3, externalities are the cost not covered by the direct user of transport modes. The Lebanese Ministry of Environment has prepared a mobility cost for Lebanon in 2015 and obtained results that are discussed below.

Externalities accounts for 34% of the total private cars transport bill in Lebanon. When comparing to the rest of the world, Lebanon presents a high energy consumption rate, 2 times the world average, and a high emissions factor, 1.4 times higher than world average.

Table 9: Transport Externalities in Lebanon [33].

Externality	*Cost* ***(USc/veh.km)***	*Cost* ***(USc/pass.km)***
Climate change cost	0.9	0.7
Pollution Cost	1.2	1.0
Travel Time	5.2	4.4
Congestion Cost	3.8	3.1
Accident Cost	5.2	4.4
Total Externality Cost	16.3	13.6
Operation Cost		
Fuel Cost	9.6	8

Lebanese Transport present high externalities, raising the point for mitigation solutions. Deployment of public transportation can reduce the total externality cost. However, to cover the quasi-total bill of transportation, **a well governing framework must also be in place.**

Conclusion: Lebanon need to develop a public transportation system, integrated in an overall framework. Specifically, GBA needs alternative modes of transportation and infrastructure development.

The transport sector is ignored on the decision-making level in Lebanon. The results are an energy, resources, and funding extensive sector as seen in the analysis. The next section will discuss a public transportation proposed solution, Beirut Bus Rapid Transit.

4.2. Beirut Bus Rapid Transit

This section is mainly based on the World Bank report [25].

4.2.1. Overview:

The National Public Transportation Program is based on three Bus Rapid Transit lines at the northern, southern and eastern Beirut entrances. Two addition loops, inside Beirut (Inner and Outer Rings), connects the three lines, forming a fully connected Network. Twenty feeder and regular buses line are also planned. The program consists of more than 1,000 buses. It will be executed on three phases, starting with northern line.

The project can be divided into three components as following:

- Component 1: BRT infrastructure, fleet and systems
- Component 2: Feeder and regular buses services
- Component 3: Capacity building and project management

The first phase consists of the northern line and the Outer ring. The northern line extends from Tabarja to Beirut (Charles Helou). It covers a 22.7 km distance. Buses will operate on a segregated line within the highway. Twenty-seven stations are to be installed, on an average distance of 860 m between one another. 120 buses will be operating at a frequency of 2 min and a speed of 40km/h at the peak hour. Each bus has a capacity of 150 passengers, to meet the demand of 5,000 passengers at peak time. And capacity could be extended to 14,000 passengers.

The outer ring is 20 km long. It will stretch over the existing ring road. Thus, BRT Lanes will be segregated only on 80% of the path, and the other 20% will be mixed with traffic. On this line, there will be 19 stations. Buses will operate at a speed of 25 km/h.

Figure 11: BBRT first phase lines [34].

4.2.2. Economic Overview:

The project's first phase is estimated to cost 345 million USD. Component one financing infrastructure and land acquisition, buses fleet and management present the highest share with 230 million USD. Although bus technology is still under study, the budget needed for the fleet is estimated by 63 million USD. Component two covering the feeder and regular buses systems is estimated by 104.4 million USD. And the third component, tackling capacity building and project management, has an allocated budget of 10 million USD.

The project is financed mainly by an International Bank for Reconstruction and Development (IBRD) Loan (225.2 million USD) and an additional amount of 69.8 million USD provided by the Global Concessional Financing Facility (GCFF) on concessional terms. The loan is provided under the terms of 31.5 years maturity and 8 years grace period. An additional 50 million USD are expected to be provided by the private sector and it will be mainly used for the Bus fleet cost.

The World Bank has done a cost-Benefit analysis for the project in 2018. The study showed a high shift toward public transportation. The expected demand is 132,000 passengers per day for the BRT, with 12,400 in peak hours only. The demand growth is estimated by 4% over a project lifetime of 20 years. This high demand will result in an economical rate of return (EIRR) of 39% and a Net Present Value of 919 million USD calculated at a rate of 8%.

In addition to the direct benefits, the project would reduce congestion by 16%, equivalent to removing 45,000 cars from the roads. This will lead to transport externalities decrease by 0.5 to 1% of the Lebanese GDP. Plus, several advantages for economic advantages will be added, such as saving 24 minutes per trip on average. From the environmental point of view, if diesel buses were used 60,590 tCO_2 will be saved per year. This quantity will increase in case of Hybrid buses to 71,902 tCO_2 per year.

Table 10: BBRT summary figures [25].

Total Cost *(millions USD)*	345
Operational Cost *(million USD per year)*	100 to 150
Project Lifetime *(years)*	20
Expected Demand *(passengers)*	132,000
Expected demand growth *(%)*	4
Number of cars removed *(cars)*	45000

4.2.3. Fares and Economic Feasibility Simulations

Several scenarios are studied to check fares cost and the need for subsidies. The input used in this section are presented in Table 10 and Table 11. For consistency, all calculation are done at the fixed exchange rate before the crisis: 1USD = 1500 LBP.

Table 11: BBRT Economic simulation inputs

Parameter	Value	Reference
Car occupancy *(Passenger)*	1.2	Road transport sector [27]
Number of cars entering Beirut from the northern entrance *(cars)*	300,000	World Bank Proposal [25]
Car user bill *(USD/pass.km)*	0.266	Mobility Cost [33]
Externalities *(USD/veh.km)*	0.163	Mobility Cost [33]
Externalities *(USD/pass.km)*	0.136	Mobility Cost [33]
Average trip distance *(km)*	9.3	Road transport sector [27]
Fuel Subsidies *(USD/liter)*	0.167	Fossil Fuel Subsidies in Lebanon [35]
Car fuel consumption *(liter / 100 km)*	8.83	Third Biennial report [26]
Minimum Wage in Lebanon *(USD)*	450	-

4.2.3.1. Scenario 1: Self-sustained project – Fares vs Passengers number:

Scenario 1 considers that fares revenues will cover the total cost (Capital and operational costs) of the project.

With a fixed total cost per year, Figure 12 presents Fares variation for different demand scenarios. For the expected demand, 132 thousand daily passengers, fare should be set at 2.4 USD/ trip, for the project to be self-financed. The expected demand is optimistic as well, it corresponds to **37%,** a high share, of the daily passengers on the northern entrance.

Or for a daily worker commuting using the BBRT, two trips are needed per day. Transport daily expenses are 4.8 USD/day. The monthly bill will be 97 USD/month, equivalent to 22% for minimal wage workers.

Conclusion 1: For a self-sustained projects, Fares are high. Fare subsidy is needed.

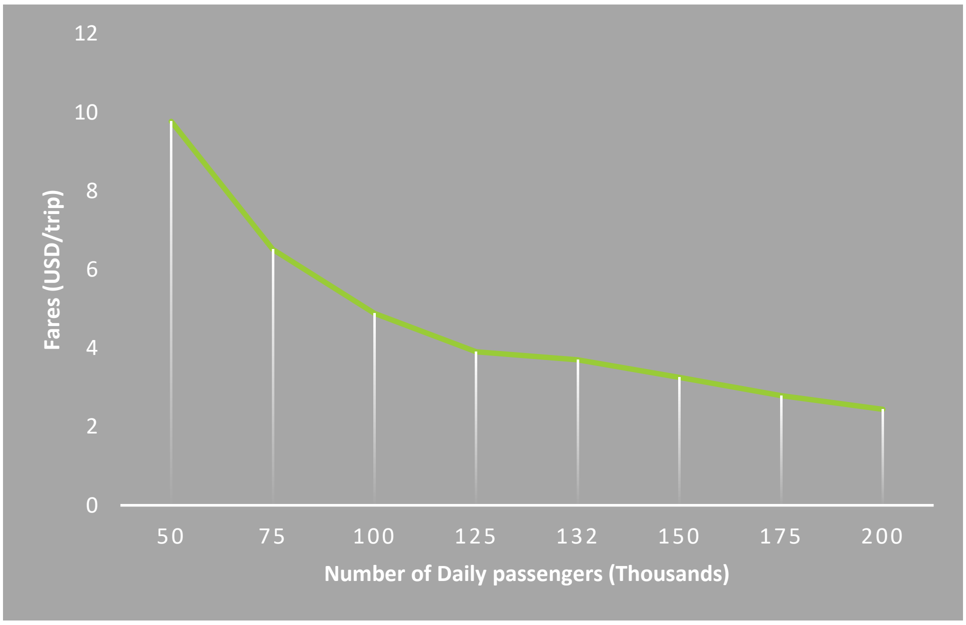

Figure 12: Fares variation in function of passengers' number.

<u>4.2.3.2. Scenario 2: Fixed Fares, what is the number of passengers needed to finance the project?</u>

For the project to be competitive, Fares must be equal or lower to the market prices. For an average trip, Car use costs 2 USD/trip. On the other hand, Tripoli – Beirut trip cost 2.6 USD (4000 LBP) by van. As BBRT is limited between Tabarja and Beirut, to be competitive a fare range between 1 and 2 USD is expected. Four fares will be fixed in this scenario: 1 USD (1500 LBP); 1.3 USD (2000 LBP); 1.7 USD (2500 LBP) and 2 USD (3000 LBP). For each of these fares, the number of passengers needed to cover the project costs is presented in Figure 13.

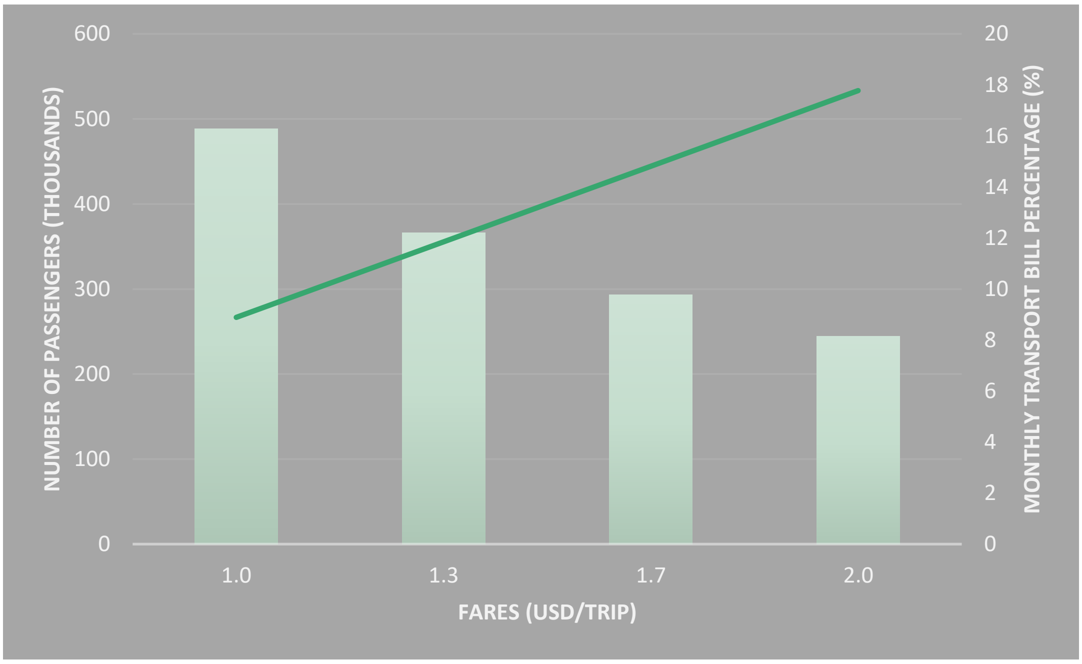

Figure 13: Number of passengers variation and Monthly transport bill percentage of the minimum wage for different fares values.

It is clear that the needed demand to ensure a competitive fare exceed the expected demand. For a fare of 2 USD, passengers' number needed is 244 thousand, near the double of the expected 132 thousand passengers. Still, 2 USD fare is an expensive bill for the low-income population. It makes up to 18% of their monthly income, but its driven from the market equilibrium.

Conclusion 2: Demand is low, passengers' number must increase to provide low tariff.

4.2.3.3. Scenario 3: Fares fixed at 2 USD, what is the subsidies amount needed in case of the expected demand?

Subsidy must cover the deficit between the revenues and yearly cost of the project. Simulation shows that for the project to be operational it relies on subsidies for the first 16 years. In the first year, the project requires 54 million USD additional funds. Subsidies decrease in the following years, due to the increase of passengers using BBRT (Figure 16). An indirect effect of the project is to reduce the fuel subsidies needed. These funds can be redirected to subsidies the BBRT fares. Still, it presents minor effects.

At the first glance, it might seem, if subsidies, the project is as costly as fuel subsidies and present a little interest.

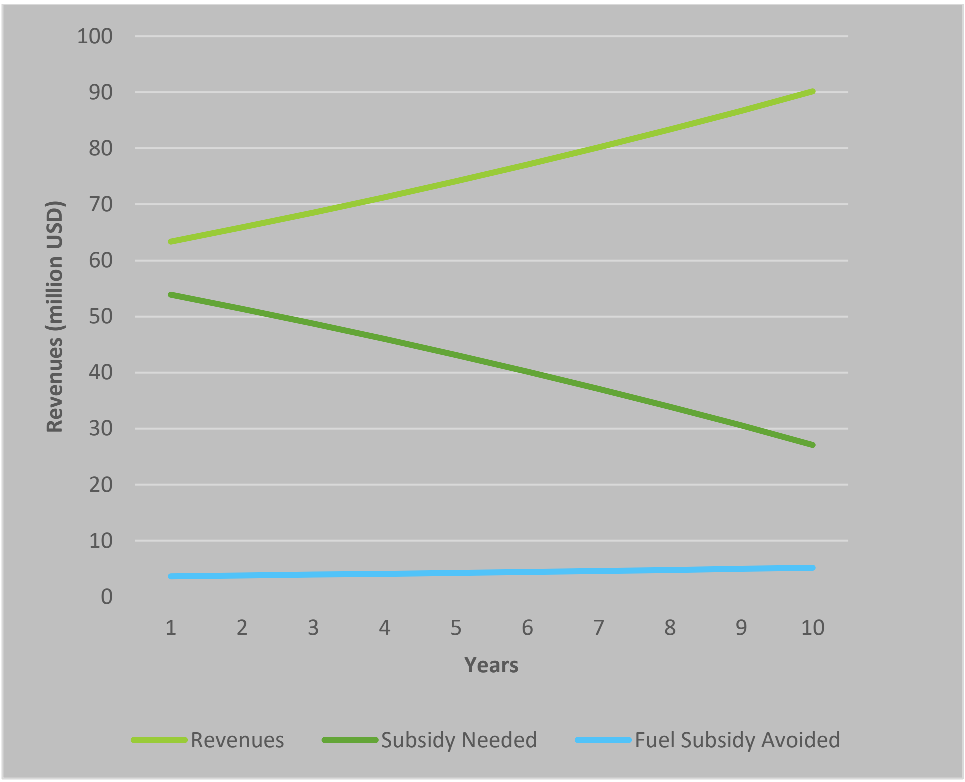

Figure 14: Revenues, subsidy needed and Fuel Subsidy avoided, at a fare of 2 USD, for the first ten year of the project.

Figure 15 presents the externalities cost avoided by removing the equivalent number of cars from the roads. For the first year alone, externalities are at 40 million USD, a clear indicator of the project's importance. It presents as well the net subsidy needed, (subsidies needed minus fuel subsidies avoided, considered diverted to support BBRT fares). Externalities exceeds the subsidies starting from the third year, creating a positive economic value on the country level.

Conclusion 3: The project is vital to reduce the overall transport bill. Still, it needs additional funds at early stage.

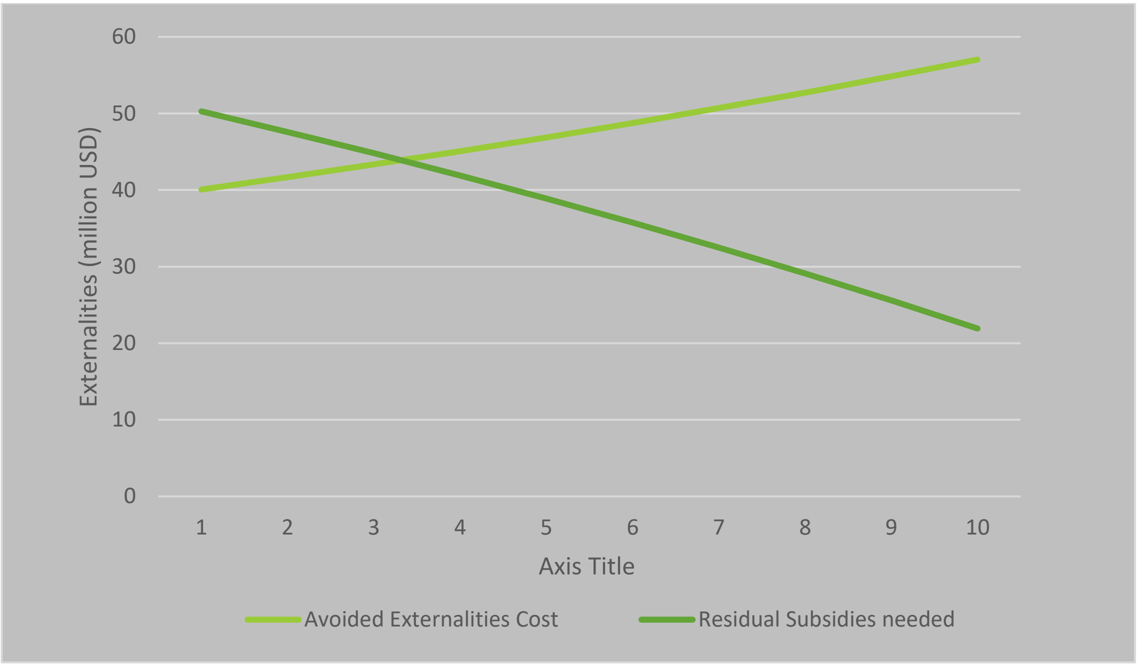

Figure 15: Externalities and residual subsides during the first ten years of the project.

4.3. Transportation Policies for Lebanon

The outcomes of the analysis in the previous section can be summarised by:

- A need to increase the passenger numbers, consequently create a shift from private cars to BBRT.
- A need to finance the project, find another revenues source.

These needs fits with transport policy roles explained in the previous chapter. Therefore, this section will discuss the applicability of transport policies in Lebanon.

4.3.1. Institutional Governance in Lebanon

First step, to a successful policy is an efficient governance and implementation. Transport responsibilities, in Lebanon, are fragmented between several institutions, without clear limitations and accountability. Figure 16 shows that the sector management is shared between 8 entities, with involvement of three different ministries. The government and both ministry of environment (MOE) and ministry of energy and water (MOEW) can be added to this list, as well, to have in total 5 ministries involved.

Mode/ Function Process	Roads	Traffic Manage -ment	Parking	Public Trans- port	Para Transit	Freight	Acci- dents	Urban Trans- port	Vehicle Regist- ration	Rail Trans- port
Policy	DGRB	TAVMA DGRB		DGLMT	DGLMT	DGLMT		DGLMT		DGLMT
Regulation	DGRB	TAVMA DGRB	DGU	DGLMT	DGLMT	DGLMT	DGRB		MOIM TAVMA	OCFTC
Planning	DGRB CDR		TAVMA	OCFTC						
Financing	MOF CDR	MOF CDR		OCFTC MOF			MOF CDR			
Project Preparation & Implement- ation	DGRB CDR MUNI						DGRB CDR MUNI			OCFTC
Operation Management		MUNI	MOIM TAVMA	OCFTC			DGRB MUNI			
Maintenance Management	DGRB	MUNI	MOIM TAVMA	OCFTC			DGRB MUNI			
User Information		MOIM TAVMA	MOIM TAVMA				MOIM TAV- MA		MOIM TAVMA	

(Source: TEAM International/CATRAM 2002)

LEGEND:

MPWT		Ministry of Public Works and Transport	
	DGRB	Directorate General of Roads and Buildings	- Within MPWT
	DGLMT	Directorate General of Land and Maritime Transport	- Within MPWT
	DGU	Directorate General of Urbanism	- Within MPWT
CDR		Council for Development and Reconstruction	
MOF		Ministry of Finance	
OCFTC		Office des Chemins de Fer et des Transports en Commun	
MOIM		Ministry of the Interior and Municipalities	
	TAVMA	Traffic and Vehicle Management Authority	
	MUNI	Municipalities	

Figure 16: Governmental Functional Responsibilities for Land Transport [24]. (*OCFTC is the French name of the Railway and Public transport authority RPTA)*

Government role is to enact the sector policies and strategy. The department of air quality within the MOE, sets the technical standards related to emissions from the transport sector. While the MOEW regulates the fuel prices and quality. Traffic management, related to the control of passenger's demand and behaviour, is the under the authority of Traffic and vehicle management authority (TAVMA) [32].

In this complicated network, several gapes arise in the sector's governance [32]:

- Lack of staff and budgets, due to the high numbers of interacting entities.
- Lack of coordination between the institutions, reflected by a mismanagement of the demand/supply, private/public transport modes… on the roads
- Missing awareness of the sector effects on the national economy and the sector management.
- A transport vision as a physical sector, with solutions limitations to infrastructure supply.
- **Absence of a comprehensive strategy for the transport sector.**

A draft for national land transport strategy was submitted in 2001, with unclear final decision about it until the preparation of the National Appropriate Mitigation Action in 2017. This is a clear evidence of government negligence to this vital sector. Or as seen in the previous section, even public transportation projects are not viable, without a transport package, including soft policies for management.

For any policy suggestion to be effective, Institutional reforms has to be applied first. Following are key recommendations, to improve the institutional governance:

- Set a national transport strategy, tackling the sector beyond the traditional infrastructure point of view.
- Reduce the number of institutions involved and decrease government's scope. With political instabilities, government absence is an obstacle for any plan development.

- Demark responsibilities for the different agencies based on clear objectives, and develop/grant power to a lead institution for an effective governance. RPTA can have this role as an inter-ministerial agency.
- Empower enforcement institutions and accord it with needed authorities.
- Build capacities within the relevant institutions and develop the needed manpower.

4.3.3. BBRT support policy

Once the institutional reforms are in place, policies deployment can become effective. To support the BBRT project, several policies can be adopted to alter passengers' behaviour. A set of several policies are adopted worldwide. The list englobes but not limited to:

- Fuel subsidies phase out
- Vehicles and fuel taxes
- Restriction of license plate
- Distance-based insurance scheme
- Land use policies
- Parking Management
- Congestion charge
- Low emissions zones

Or to be effective policies should be coupled with alternative mode of transport. In the studied case, BBRT service covers only Beirut Entrances. Therefore, applying a national wide policy, such as fuel taxation, creates injustice and exposes other regions for additional taxation and social inequality. Based on this, only congestion charge and Low emissions zone will be considered, because they are local solutions with good previous results.

Several policies can be adopted at the same time, still for the purpose of this project only one policy will be considered.

4.3.3.1. Congestion Charge vs. Low Emissions Zone

Based on Table 12, The integration of Low-emissions zone in GBA is easier than congestion charge, because it tackles air pollution, a direct problem for the population without hindering their access to their private cars. Congestion charge on the other side, is expected to face opposition because it limits the freedom of car use, and most importantly because of the typical view of transport solution as infrastructure and buses.

But in the context of BBRT, congestion charge has more impactful support, because it enforces the shift toward public mode of transportation, and by that increasing the BBRT passengers' number. Or LEZ has a minimal effect on this point, because the user could upgrade its car to meet the new regulation.

Following this analysis, Congestion charge applicability will be considered in the next section, to be aligned with BBRT project.

Table 12: Strength, Weakness, Opportunities and Threats (SWOT) Analysis for Congestion charge and Low emission Zone in Greater Beirut Area.

	Internal		External	
	Strengths	Weakness	Opportunities	Threats
Congestion Charge	- Effective on reducing car use - Generate revenues - Reduce externalities	- Application enforcement and non-compliance detection - Adequate design - Social Equity	- Growing vehicle fleet and road saturation - Need for a solution for congestion problem in GBA	- Public acceptance - Institution's fragmentation - Lack of awareness about the importance of transportation policy on decision making level
Low Emissions Zone	- Effective on upgrading car fleet specifications - Generate revenues - Reduce air pollution	- Social Equity - Non-compliance detection	- Public support as a solution for pollution problem in Beirut - Probability for Political buy-in	- Population capacity to meet the new regulation and update their cars - Institution's fragmentation

4.4. Congestion Charge Applicability

This section presents a preliminary study for the application of Congestion Charge in Greater Beirut Area, as a support policy for public transportation projects, BBRT. The study will pass through the policy application characteristics and the expected effects on modal shift.

4.4.1. Scope – Geographical application

In theory, optimum application suggests different charges on different roads, depending on the demand on the road section. Practically, this solution may not be feasible.

A high number of scenarios can be considered for zone defining, however, only two options will be considered in this report: Congestion Charge within Beirut outer ring area and on Beirut entrances only. Table 13 gives an overview of both characteristics.

Table 13: Comparison of Congestion Charge geographical application scenarios [36].

Application Scope	Inside Outer Ring Zone Application	Beirut Entrances Bottleneck Application
Advantages	- More efficient in the case of inter-zonal traffic	- Charge on passage, higher efficiency on car use through the city entrances - Relatively simple application
Disadvantages	- Enforcement more expensive - Competing Interaction with other transport policies (ex: parking policies)	- Little to small effects on congestion within Beirut - Charge per passage, high charge in case of multiple passages is necessary - Little efficiency on Inter-zonal traffic

Besides, Beirut entrances, the inner city suffers from high congestion in different regions like Hamra, Ashrafiyeh, Verdun… Adding to this that the city has a relatively small area, where roads congestion is not limited to few roads section but is a results of zone interaction. Other fact is that Beirut is bordered from the west by the Mediterranean Sea, limiting the number of entrances.

Following the analysis above, and driven by the fact that transport sector must be treated as a whole not in pieces, Zone Application is considered to be more adequate in Beirut context. This means that vehicles will be subject to fees to enter and circulate within the city. Figure 17 shows the zone coverage on Beirut's map.

4.4.2. Detection Technology

Technology is a determinant factor of the policy efficiency. Capture rate is essential for compliance enforcement. The capture rate is however a function of the technology and the number of units deployed as well [36].

Table 14 presents the capture rate, Capital cost and operational costs for different enforcement schemes. Numbers are based on the LEZ review report prepared for London.

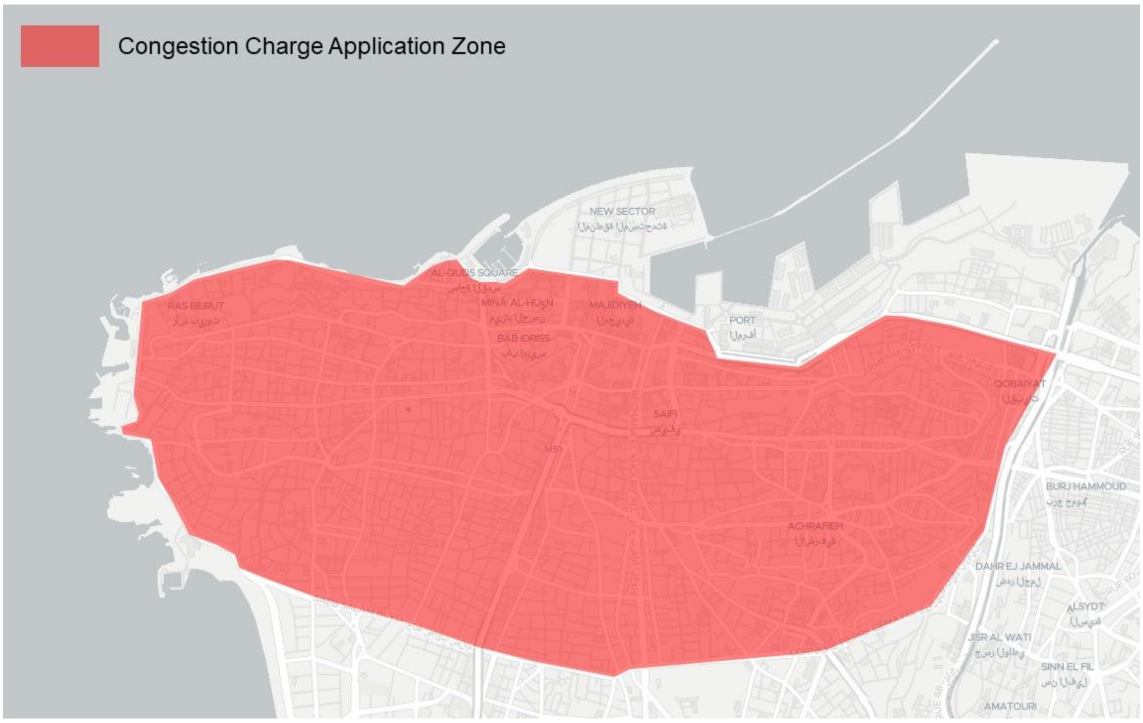

Figure 17: Proposed Congestion Charge Application Zone in Beirut.

In terms of technology, the same enforcement method can be applied for LEZ and Congestion charge. But in terms of country context, operating cost are expected to be lower in Lebanon, taking into account the difference in wages. Still in the context of the preliminary study, no correction will be done on the operating costs. Thus, results are more conservative.

Table 14: Detection Technology characteristics [37].

Technology	Capture rate (%)	Capital Cost (Million USD)	Operations cost (Million USD)
Manual Enforcement (10 units)	3	0.41	1.62
Manual Enforcement (20 units)	5.7	0.81	3.11
Manual Enforcement (40 units)	11	1.62	6.22
Cameras Enforcement* (23 cameras)	28	4.47	3.79
Cameras Enforcement* (67 cameras)	50	8.66	5.82
Cameras Enforcement* (125 cameras)	70	11.91	9.61

**10 additional manual units are considered.*

Cameras' deployment is evidentially more effective in detection. On the other hand, it is at least two times more capital expensive than manual enforcement. Despite this disadvantage, for the policy to achieve its goal, cameras technology Should be considered.

Beirut geographical advantage must be highlighted. The long coastal line and Beirut River present natural barriers for evaders. This will lead to a concentration of cameras on key entry points, which expect to increase the detection rate for the same number of cameras deployed.

In total, forty-two entrances were detected by map analysis. The entrance can be divided into two categories: 7 multi-level entrances (bridge/tunnel combined with ground level road), and 35 one level entrance (only ground level road).

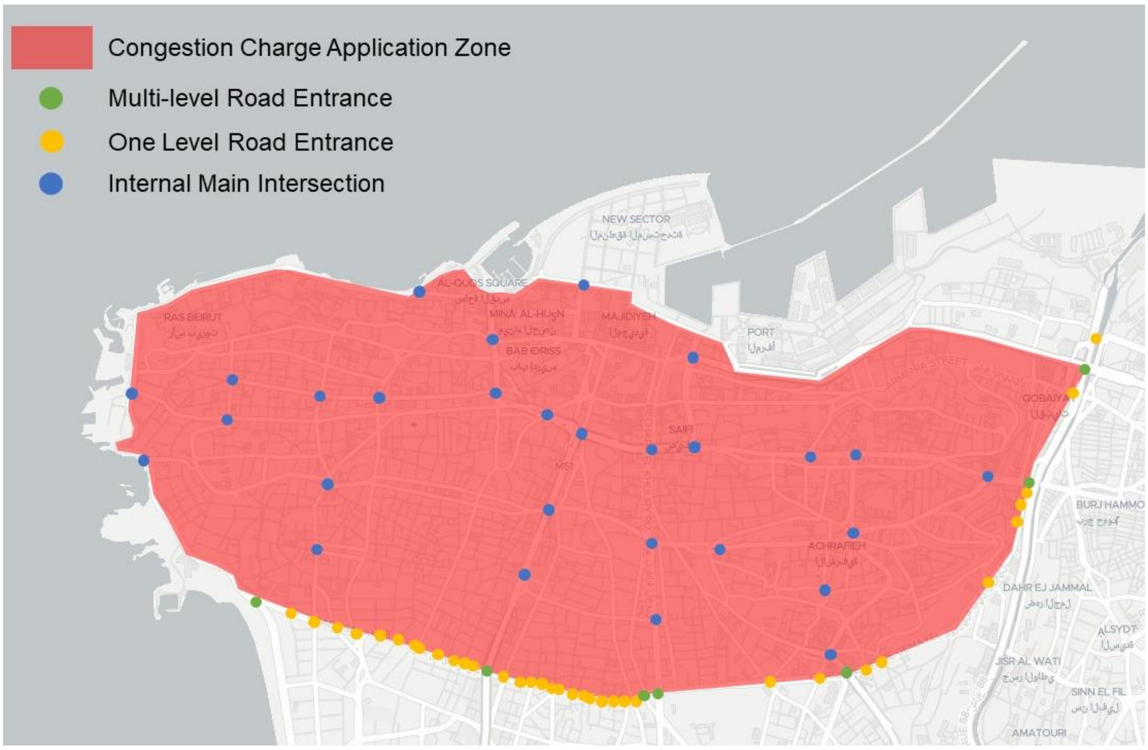

Figure 18: Proposed Congestion Charge Zone entrances and key intersections.

Aiming at a 50% detection rate, A minimum of 67 cameras should be installed in addition to another 10 manual operators. Cameras distribution are presented in the table below and on Figure 18.

Table 15: Cameras distribution.

Location	Number of cameras (Total number)
Multi-level entrance	2 (14)
One level entrance	35
Within Congestion Charging zone	28

Two cameras are considered on the multi-level entrances, due to high flow and for higher efficiency. The 28 cameras within the congestion charge zones are distributed randomly on Beirut's key intersection. Figure 18 present the cameras distribution over the studied area. This configuration is not the optimum. Entrances' cameras can be reduced due to overlapping detection sections on the outer ring. Nevertheless, the map shows a high coverage of mains transport lines within Beirut, accordingly as explained before, higher detection rate is expected for the same number of cameras. A second distribution, Figure 19, presents less cameras on the entrances, due to the fact that some entrances share the same outer ring flow section, thus can be covered by one camera. This distribution shows a wide coverage within the proposed zone with 41 cameras inside the zone, approving the higher efficiency hypothesis.

Independently from the analysis done, the optimum distribution should base on the study of traffic flow data.

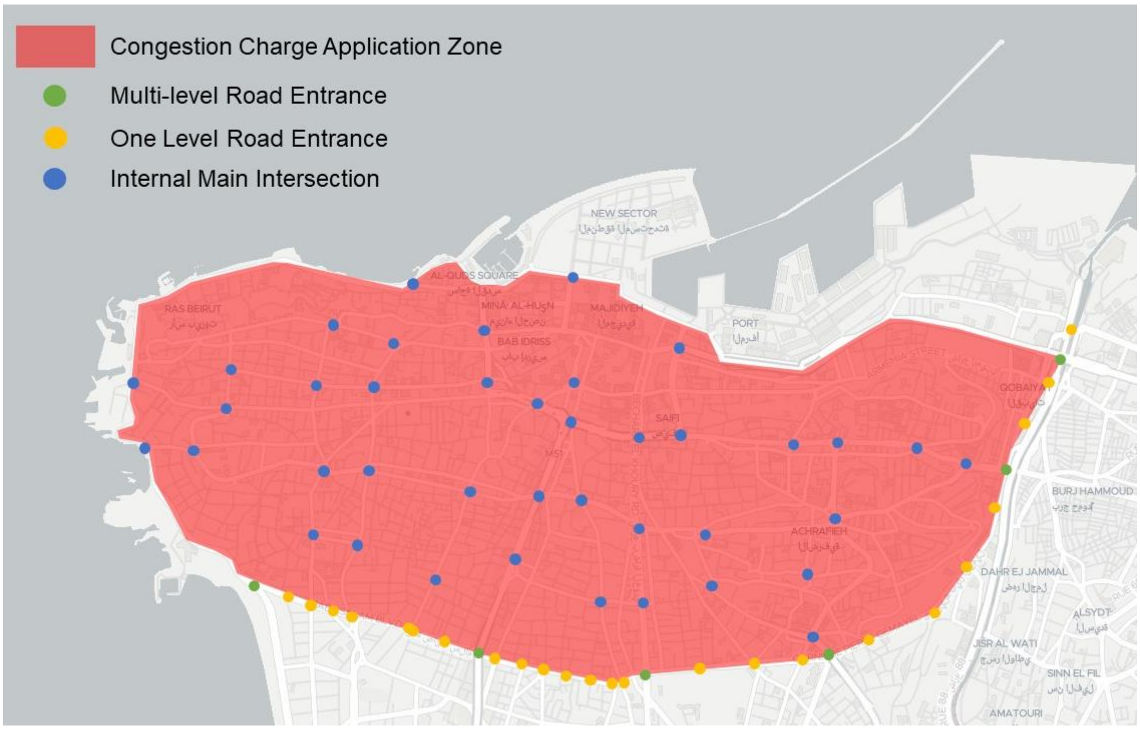

Figure 19: Second proposed distribution taking into consideration that some entrances have the same inflow from the outer ring.

4.4.3. Fees and Fines

By definition, the charge aims to increase trip cost for the user to bear their external effects. This principal is refereed as marginal social cost pricing (MSCP) [38] (Figure 20). It consists on increasing the cost to reach the optimal charged equilibrium. Hence, the optimal fee should cover the congestion externalities of the average trip, **0.35 USD (530 LBP).** It is the product of congestion externality and average trip distance. The value is relatively low, which increase the chance for public acceptance.

To note, that this method is not the optimum, a separate economic modelling should be done to find the best fee taking into consideration demand elasticity and several other parameters.

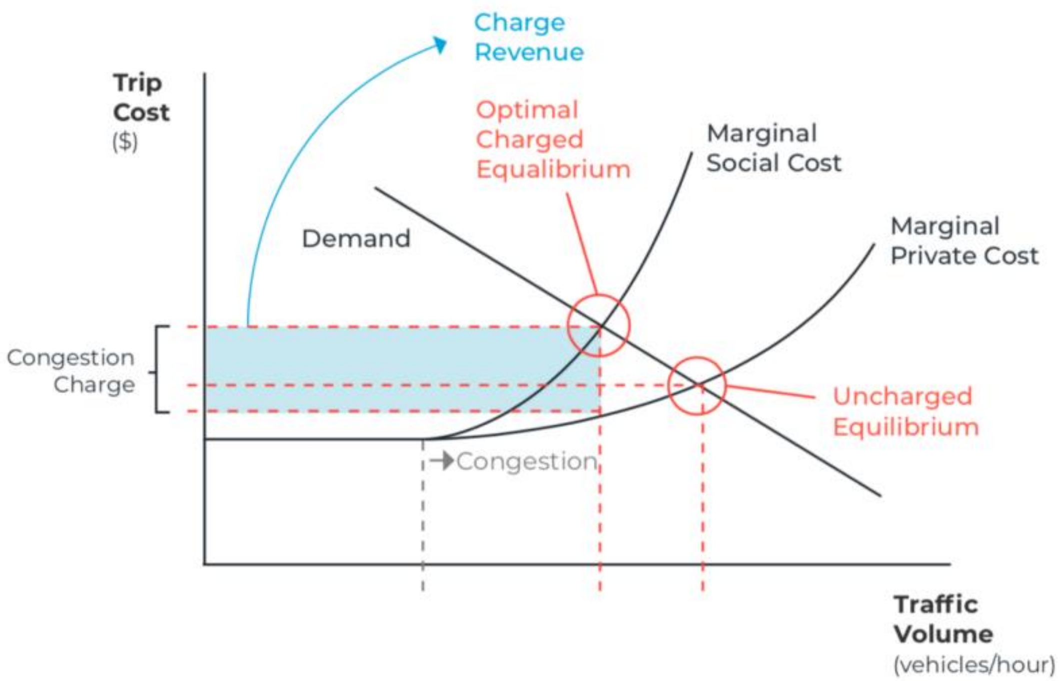

Figure 20: Congestion Charge Economic Theory [39].

Evaders' probability to get caught is 50%, based on the scenario adopted above. In other words, if a passenger is entering the charging zone for 2 days, he might be caught only one day. For this reason, fines must cover all both days fees, considering a total non-compliance. The minimum fine should be **0.7 USD (1,050 LBP)**. However, such a low fine could encourage non-compliance, and higher fine are encouraged. Following the same fine/fee ratio, fourteen, as in London, Fines can be set at **5 USD (7,500 LBP)**.

4.4.4. Exemptions and Operation Hours

Public transportation must be exempt from the fees to encourage modal shift and the development of this sector. Other common exemptions are firefighting trucks, police, ambulances…

Operations hours can be limited to congestion period based on traffic flow data. Due to the use of zone charging limited operations hours, during congestion hours, would acquire more social acceptance. In addition, it allows more flexibility for Beirut residents.

4.5. Congestion Charge Economic Feasibility (without BBRT)

This section will verify the impact of Congestion charge on the current transport situation in Beirut. The goal is to verify if the policy, by itself, is financially profitable and could be a potential financing source for BBRT project. In addition, the environmental impact will be assessed.

The key factor in CC evaluation is to determine the number of shifting passenger. Or due to the lake of data, the elasticity between mobility cost and passenger demand is hard to estimate. A separate study, done in 2018, has evaluated the effect of gasoline prices on fuel efficiency [40]. The findings were:

- A 1% increase in gasoline prices, increase the sales of new midsize cars by 1.35%
- A 1% increase in gasoline prices, increase the sales of fuel-efficient cars by 1.12%
- A 1% increase in gasoline prices, increase the sales of used efficient cars by 1.5%

These results reflect the elasticity of car purchase and gasoline prices. The average elasticity is 1.72. However, fuel cost represents only 76% of the user operational cost. Therefore, Car demand's elasticity, in relation to mobility operation cost, will be higher. The average elasticity calculated is 2.28. Or within the absence of public transportation in Lebanon, the seek for different car, following a gasoline price increase, can be regarded as a transport mode shift. When applied, CC's fees will be added to the total operational cost. Therefore, this result will serve as an elasticity magnitude estimation in the rest of our calculation.

In the next step, passengers' shift will be modelled considering several fees and elasticity values. All modelling inputs are presented in Table 16. Elasticity step is taken 0.5, derived from the high elasticity value found above. Fees values are chosen based on 500 LBP (calculated previously) as a start point.

Congestion charge revenues can be classified into direct revenues, money that will be available in the government budget, and indirect, the amount of externalities reduced. Direct revenues have three streams: CC's Fees and fines and fuel subsidies avoided. Figure 21 presents the direct revenues per investment of CC application. Independently from the elasticity-fee combination, each dollar invested in the new policy generates a minimum of 1.8 USD. This lower limit is a consequence for subsidies avoided amount, when all passengers shift from their private cars to another transportation mode.

Table 16: Congestion Charge Economic Feasibility Inputs parameters.

Parameter	Value	Reference
Congestion Charge CAPEX *(USD)*	8,660,000	Deloitte [37]
Congestion Charge OPEX *(USD)*	5,820,000	Deloitte [37]
Total Number of cars at Beirut Entrance *(cars)*	650,000	World bank Proposal [25]
Evader potential *(%)*	20	Deloitte [37]
Cameras' detection probability *(%)*	50	Deloitte [37]
Average trip *(km)*	9.3	Road Transport Sector [27]
fuel consumption* *(liter per 100 km)*	8.8	Third Biennial Report [26]
London Fees / fines ratio	14	London fact sheet
Mobility operational cost *(USD)*	0.127	Mobility Cost [33]
Mobility fuel cost *(USD)*	0.096	Mobility Cost [33]
Total externality cost *(USD)*	0.163	Mobility Cost [33]
Average Elasticity*	2.28	Effects of Gasoline Prices [40]
Subsidies* *(USD per 20 litres)*	3.34	Fossil Fuel Subsidies in Lebanon [35]
CO_2 Emissions* *(g/km)*	218	Third Biennial Report [26]
NO_x Emissions* *(g/km)*	1.68	Third Biennial Report [26]
CO Emissions* *(g/km)*	20.88	Third Biennial Report [26]

**Average value*

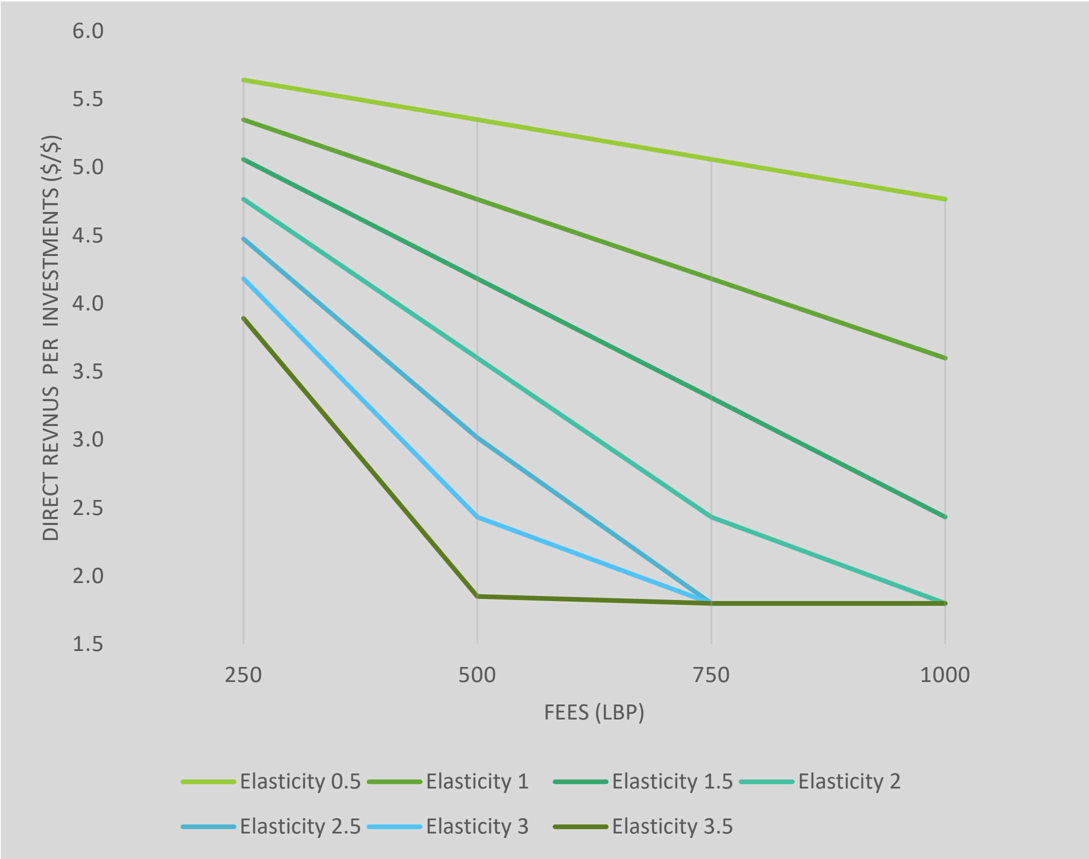

Figure 21: Congestion Charge Direct Revenues generated (Fees + Fines + Fuel subsidies avoided).

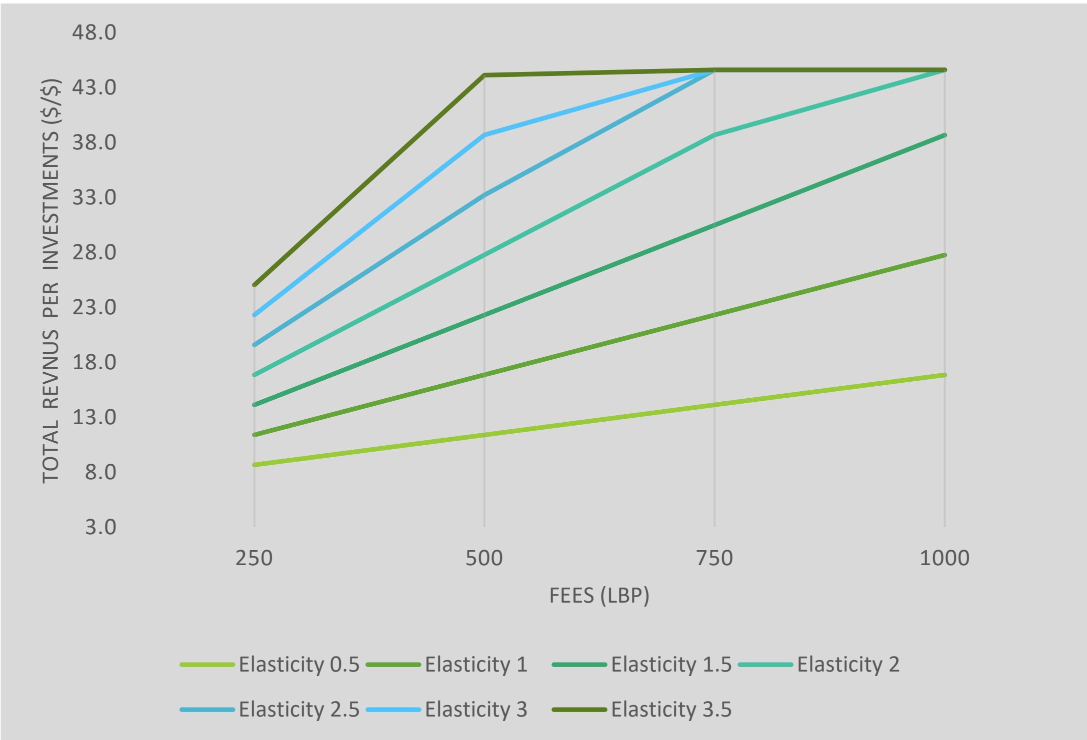

Figure 22: Total Congestion Charge revenues (direct +indirect) per investment.

Aside from the lower limit, Direct revenues reaches 5.5 USD per dollar investment, at low elasticity and low fees. In this case, users choose to pay the fees and keep using their cars.

Conclusion 1: Congestion charge is a good investment, and it generates important revenues to the government.

If extending the impact compass to externalities, the benefits of congestion charge will increase significantly. Figure 22 shows that the minimum revenues per investment rise from 1.8 to 8.7. The maximum, as well, is capped at 44.6 USD per USD invested. This upper limit is a result from the maximum externalities value when all the passengers leave their cars. However, this is a theoretical return on investment, because externalities are not paid. Still the number gives an estimation of the indirect advantages and the economic impacts.

Conclusion 2: Congestion charge reduces transport externalities and it generates indirect budget revenues.

After verifying that it is a valid investment and could support public transportation projects. It is interesting to see the total amount of revenues and if it is in the same order of magnitude of subsidies needed for BBRT. For this reason, elasticity is fixed at 2 (a slightly conservative value to the 2.28 found previously). And Fess are set at 0.3 USD.

The implementation cost is 9 million USD, while the yearly operating cost is 6 million USD. The net direct revenues, for the first year, is 23 million USD. BBRT highest deficit was estimated at 50 million USD. These values proves that the application of congestion policy can covers half of the subsides needed and help in sustaining public transport projects.

For the same inputs the amount of externalities avoided is 133 million USD (Figure 23). These indirect revenues can also be redirect toward transportation projects.

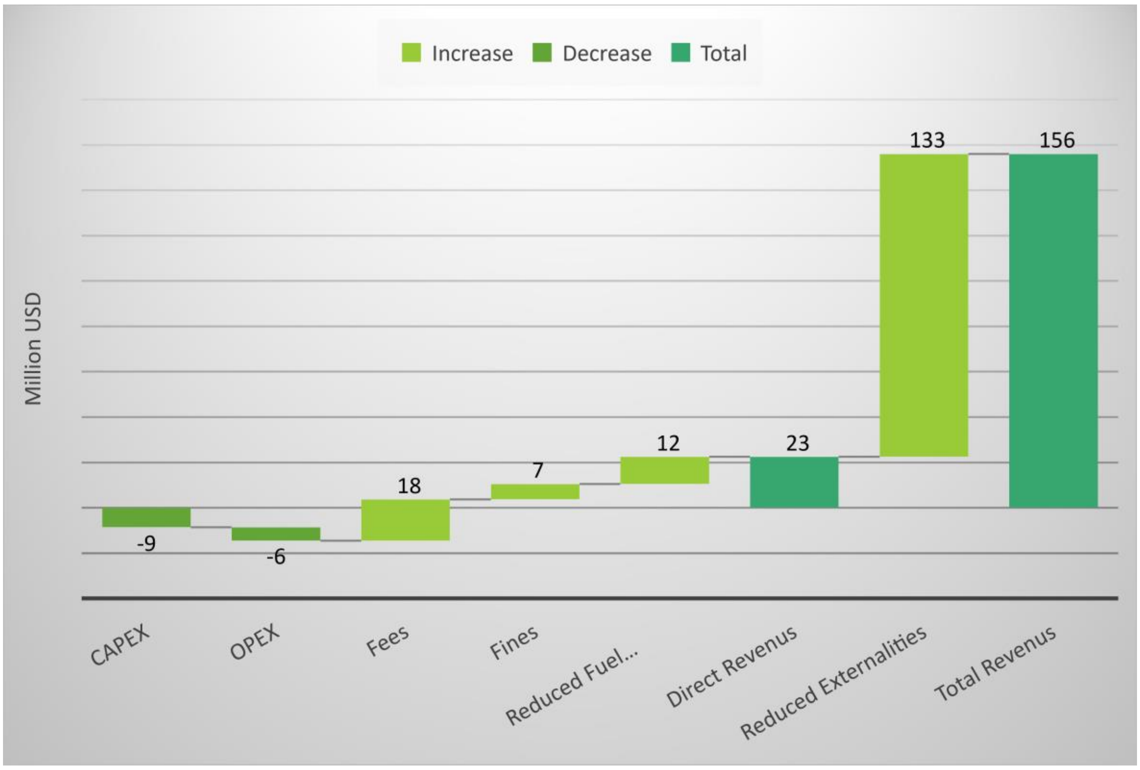

Figure 23: Congestion charge financial numbers for the first year, at an Elasticity =2 and a Fees = 0.3 USD.

Conclusion 3: Congestion charge application can finance public transport projects.

The impact on pollution is also interested to evaluate. Due to the extensive use of cars, air pollution is an increasing problem in Beirut. The application of well-designed transport policy could help alleviate this problem. For congestion charge possible reductions is presented in the table below.

Table 17: Emissions reduction by congestion charge application (at a fee=0.3 USD and elasticity =2).

Pollutant	Quantity Reduced *(tonnes per year)*
CO_2	178,520
NOx	1,376
CO	17,033

Conclusion 4: Congestion charge helps addressing environmental and pollution problems.

The purpose of this section was to prove the benefit of CC application, and in any case, CC should not be implemented separately of public transportation projects, as it is then transformed to an additional tax on the population. As concluded in the analysis of the current situation, there is a highly need for alternative mode of transportation. Policies are enablers of these modes and not solution by their own.

4.6. BBRT and Congestion Charged Coupling

In this section, the interaction between both BBRT project and Congestion charge, if applied together, are evaluated. As BBRT first phase is limited to the northern entrance, the total number of cars is taken at 300,000 cars. Furthermore, the effects of congestion charge are considered on the northern entrance only, taken that on the other entrances there are no alternatives, thus no modal shift. The same inputs of the previous sections are used, in addition to:

- Car increase percentage on the road: 3% - The percentage is the average increase in Lebanon vehicles fleet presented in page 48 . The increase is considered linear over the Lebanese territory; thus the same percentage applies on.
- BBRT Capacity/expected demand factor: 2.8 – This ratio is calculated by the value of expected demand at peak hour (5,000 passengers) and the possible accommodation of the buses (14,000 passengers) [25].

All calculations are based on the assumption that modal shift is limited from cars to the new BBRT system.

The analysis of BBRT concluded in the need to:

- Increase passengers' number
- Finance the project

In response to the first objective, it is important to monitor BBRT demand's variation.

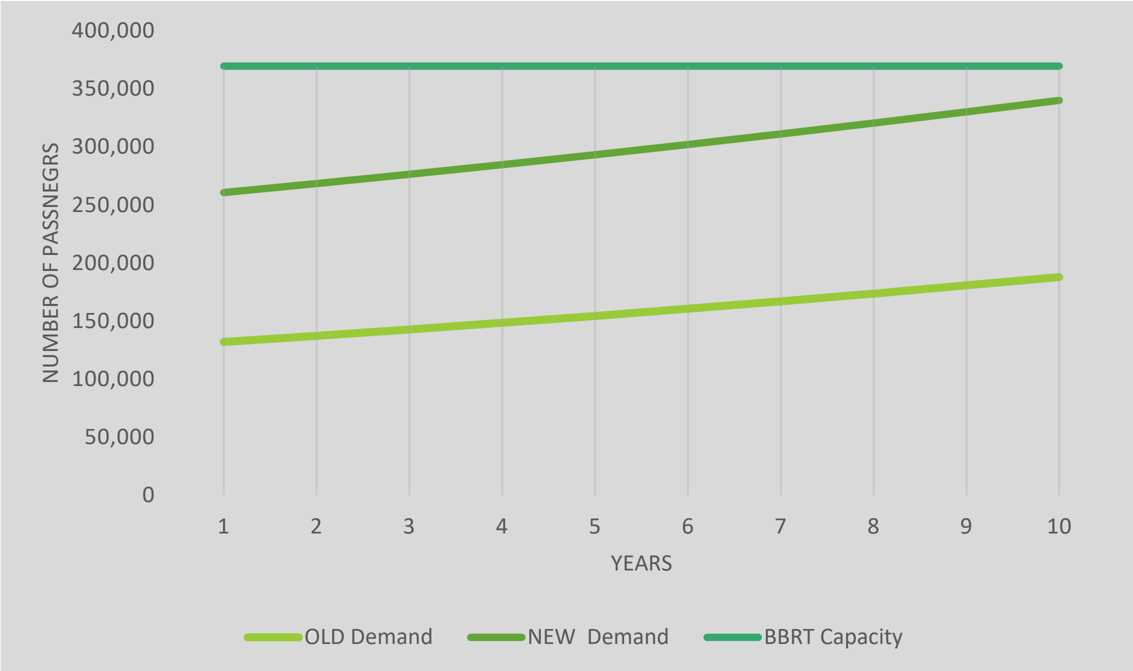

Figure 24: BBRT Demand variation, by the CC implementation at a fee of 0.3 USD.

Figure 24 shows the increase of BBRT passengers, after the implementation of congestion charge policy. Demand is ***2 times higher*** than the initial case. One hundred and seven thousand additional cars were removed from the street, equivalent to 128,000 new passengers. The capacity of the initial bus system is capable to cover the total demand, until year 13 of the project lifetime. Therefore, there is no additional capital cost on the system considered.

Or in reality, higher number of passengers will lead to higher operation cost. Higher weight, in the buses, certainly increase fuel consumption. Plus, higher usage results in higher maintenance rate. The increase of operations cost is hard to estimate, this is why several cases will be considered: an increase of 0,5,10,15,10 and 25%. To note that 25% is a conservative case, where the operating cost is increased by one-quarter of the initial amount.

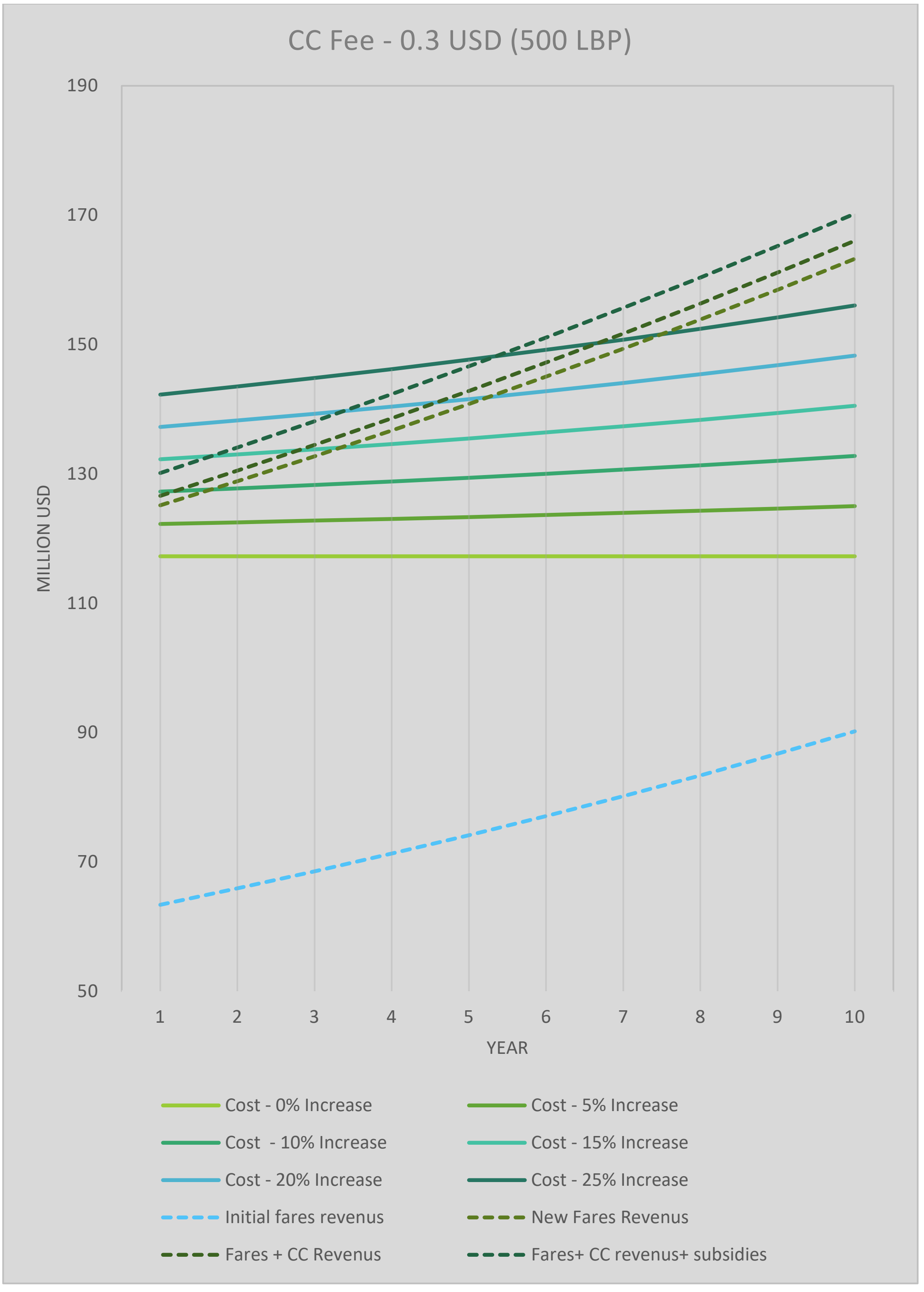

Figure 25: BBRT Cost and Revenues within the implementation of CC (Fee = 0.3 USD).

The revenues of BBRT have significantly increased. The project become profitable since the first year, assuming that operation cost increase is lower than 10% (Figure 25). If the fuel subsidies savings and the CC revenues are also diverted to finance the project, the project will become profitable even for an increase of 15% on operation cost.

Compared to the initial revenues, it is clear that congestion charge has helped to cover a large share of the project deficit. These results make the project more sustainable.

However, with a slight deficit in the first years, it is interesting to see the impact of higher CC fees, and if it is possible to make the project totally independent.

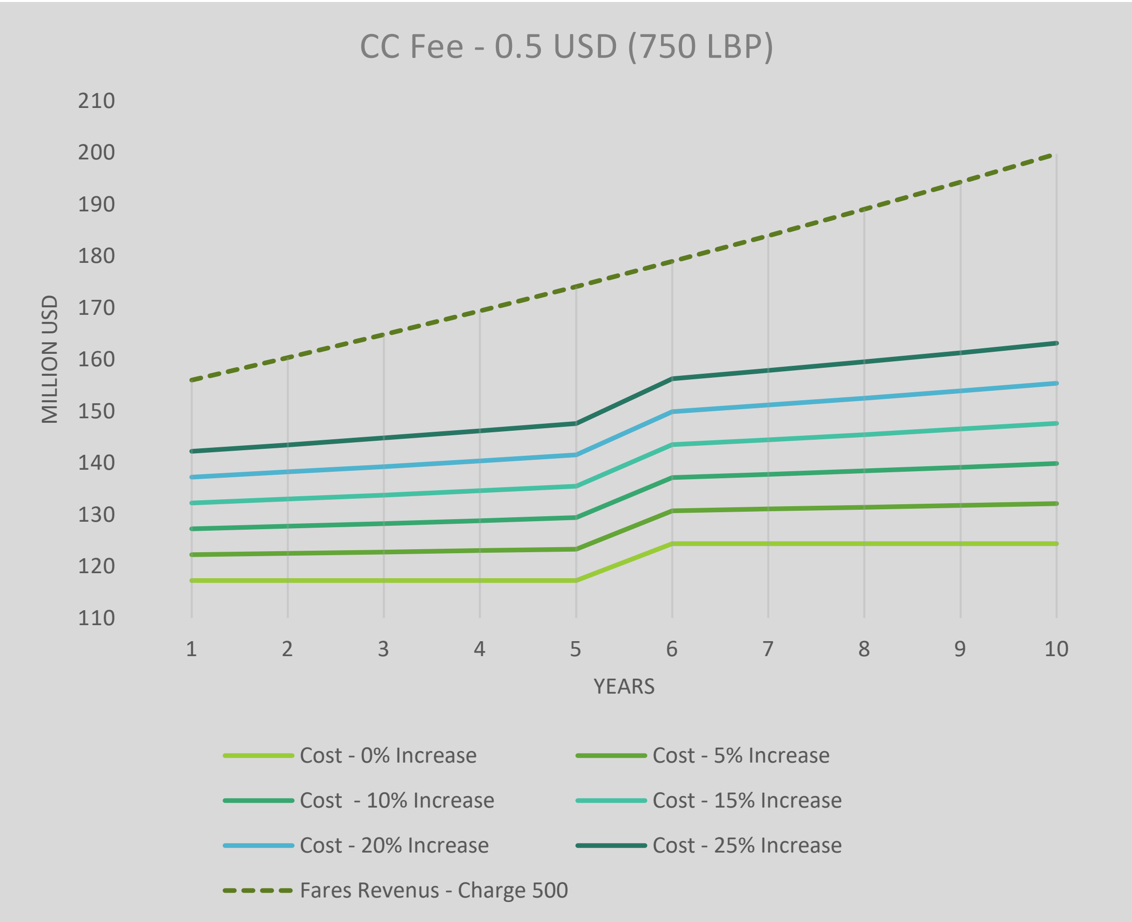

Figure 26: BBRT Cost and Revenues within the implementation of CC (Fee = 0.5 USD).

For a fee of 0.5 USD, BBRT fares revenues will exceed the cost and the project is profitable since the first year, Figure 26. Even if the buses capacity is fulfilled earlier, on year six, profit can easily cover the capital costs needed to provide additional supply.

This is not to mention the high number of externalities avoided. These amounts even if not directly collected, it has indirect effects such as boosting the economy, saving time, reducing pollution…

Conclusion 1: The coupling between BBRT and Congestion charge will heavily reduce subsidies needed to finance the project and even make the project generate revenues in certain cases.

Another advantageous point of the supporting policies is the environmental impact.

Table 18: Environmental impacts of BBRT and CC.

Pollutant	***Emissions reduced*** *(tonnes per year)*
CO_2	***105,706***
NOx	***815***
CO	***10,125***

BBRT and Congestion charge application can achieve 3% of Lebanon reduction target mentioned in the Nationally Determined Contributions (NDC) [41]. In other words, CO2 reduction by both projects, is equivalent to ***4.8 million trees.*** Another important impact of these two projects.

Conclusion 2: Both projects have a significant reduction of transport pollutants.

4.7. Social Impact of Congestion Charge Application

At a fee of 0.3 USD, the monthly CC fees will sum up to 10 USD. It is equal to 14% of the monthly user cost. And it accounts for 2% of the monthly income for a minimum wage employee. These figures are relatively high for the vulnerable population. Additional measures should be applied to address the equity problems.

Again, Congestion charge should never be implemented alone. Coupling the policy with BBRT is one measure to provide a good service alternative for the low-income population. Public transportation facilitate access to basic services, and it lower the transport bills compared to car use, even without CC implemented. These two measures together provide adequate transportation services, while being financed by the wealthiest share using their cars.

Another advantage, is that CC reduce air pollution. Studies shows that lowest income people are the most one exposed for pollution, while they are the least likely to own a car [20].

Providing incentives, and support of other form of mobility is an additional way to address equity. The supply of cycling and walking appropriate infrastructure can facilitate the shift toward other mode of transportation. Subsidies public transportation fares and other financial incentives are also a solution.

Special rules and exemptions are used for social equity as well, still this option is limited. Higher number of exemptions can reduce the efficiency of the policy.

All in all, congestion charge is more advantageous to the lowest income population in the context of Lebanon, due to the bad transportation services that this share can afford. However, additional measures should be considered to ensure higher social equality.

CHAPTER V

CONCLUSION

Transportation is an important sector. It is a key intersection between the different economic and social services within a country. Transportation is a major concern for decision makers in the sustainability context. The sector consumes a high amount of energy and emits 24% of total CO_2 emissions worldwide.

This thesis has tackled this sector, driven by its importance. Chapter three has explored in depth the urban transportation problem and summarised a key parameter to help describe transport's situation and assess the intensity of this problem.

Chapter four explored transportation policies as a solution for urban transportation. Plus, two policies examples were highlighted: Congestion charge and Low emissions zones.

The outcomes of these chapter were than applied to the Lebanese cases in chapter five. The chapter was divided into three main sections:

1. In Section one, the urban transport problem in Lebanon is presented and evaluated using chapter three outcomes' parameters. The results identified the **need for public transportation,** in the first place, and other alternatives to break the dependency on private cars. Second, plans or projects must be well designed and planned, in a national transport framework context.
2. In Section two, an economic analysis is done to the Beirut Bus Rapid Transit project. **The project is economically in deficit and require higher passengers'**

number and public subsidies. For the first year alone, 50 million USD of subsidies are required.

3. Section three discuss the applicability of Congestion charge as a support policy to surpass BBRT hinders. The first outcome is a **need for institutional reform in Lebanon, to ensure an effective policy implementation**. Second, **Congestion charge presented a very effective support to the BBRT** project by minimising subsidies needed and make the project totally profitable, at a fee of 0.5 USD. Coupling both initiatives also help achieves environmental goal and reach 3% of Lebanon's NDC. Third, despite its advantage, **additional measures are needed to ensure a social equity** within congestion charge application.

The thesis has proven the need for soft policies to govern the transportation sector in Lebanon. The results can be taken further in a detailed study for the social implications of congestion charge. And a comparison with other policies is interesting as well to help decision makers choose the appropriate tools.

REFERENCES

[1] "Analysis of The Links Between Transport and Economic Growth," Organisation for Economic Co-operation and Development, 19-Apr-2004.

[2] "Transport," in *Climate Change 2014 Synthesis Report Fifth Assessment Report*, IPCC, 2014, pp. 599-670.

[3] D. Banister, Unsustainable Transport; City transport in the new century, New York: Routledge, 2005.

[4] "Tracking Transport Report," IEA, Paris, 2020.

[5] " Global energy use in various end-use sectors," IEA, Paris, 2009b.

[6] "Global Mobility Report 2017," Sustainable mobility for all, 2017.

[7] *The Millennium Development Goals*, UN Department of Public Information.

[8] "Analysis of the transport relevance of each of the 17 SDGs," UN-Habitat, UNEP, SloCat, 2015.

[9] *Final list of proposed Sustainable Development*, Inter-Agency and Expert Group on Sustainable , 2016.

[10] *68% of the world population projected to live in urban areas by 2050, says UN*, UN Department of Public Information, 2018.

[11] C. Bianchi, Strategic Planning for Urban Transportation, Palermo: Springer, 2020.

[12] P. Newman and J. Kenworthy, The end of automobile dependence, Washington: Island Press, 2015.

[13] "Handbook on The External Costs of Transport," European Commission, Brussels, 2019.

[14] S. Yedla, Urban Transportation and the Environment, India: Springer, 2015.

[15] Formulating an Urban Transport Policy, Washington: World Bank , 2014.

[16] B. V. Wee, J. A. Annema and D. Banister, The Transport System and Transport Policy, Massachusetts: Edward Elgar Publishing limited, 2013.

[17] K. S. Holger Dalkmann, Low Carbon Green Growth Roadmap for Asia and the Pacific, UNESCAP, 2012.

[18] E. C. o. M. o. Transport, Sustainable Transport Policies, Prague: OECD, 2000.

[19] S. Ye, "Research on Urban Road Traffic Congestion Charging Based on Sustainable Development," *Physics Procedia*, vol. 24, pp. 1567 - 1572, 2012.

[20] I. Kristoffersson, L. Engelson and M. Borjesson, "Efficiency vs equity: Conflicting objectives of congestion charges," *Transport Policy*, vol. 60, pp. 99-107, 2017.

[21] "Low-Emission Zones are a success - but they must now move to zero-emissions mobility," Transport and Environment, Brussels, 2019.

[22] A. H. Amundsen and I. Sundvor, "Low Emissions Zones in Europe," Institute of Transport Economics Norweagian Center for Transport Reaserch, Oslo, 2018.

[23] X. Bernier, "Lebanon viewed through its transportation network," *Asia and Pacific Stusdies*, vol. 7/2010, pp. 33-49, 2010.

[24] "Transport Sector," Development Program 2006-2009, 2009.

[25] Z. S. E. Nakat, "Project Appraisal Document on a Proposed Loan in The Amount of US$295 Million (Including support from the global concessional financing facility) to the Lebanese Republic for a Greater Beirut Public Transportation Project," The World Bank, February 22, 2018.

[26] L. Kai and Y. D. Chalfoun, "Lebanon Third Biennial Update Report on Climate Change," Ministry of Environment, Beiut, 2019.

[27] "Road Transport and Air pollution," IPTEC, UNDP, ESCWA, MoE, Beirut, 2016.

[28] "TNA mitigation transport".

[29] "Labour Force and Household Living Conditions Survey 2018-2019 Lebanon," Central Administration of Statistics, Beirut, 2019.

[30] R. Salameh, M. Abou-Zeid and I. Kaysi, "Neighborhood Initiative Project Congestion Studies," American University of Beirut, Beirut, 2013.

[31] L. Kai, V. Kabakian and R. El-sheikh, "Technology Needs Assessment for Climate Change," Ministry of Environment, Beirut, 2012.

[32] "Nationally Appropriate Mitigation Action in Lebanon's Private Road Transport Sector (FEVs)," Ministry of Environment , Beirut, 2017.

[33] J. Stephan and L. E. Sayyed, "Mobility Cost, Case study for Lebanon," Ministry of Environment, Beirut, 2015.

[34] "Resettlement Action Plan (RAP) for The Bus Rapid Transit (BRT) System Between Tabarja and Beirut and Feeder Bus Services," Council for Development and Reconstruction, Beirut, October 16, 2017.

[35] L. E. Sayyed, W. Sayegh, E. Saliba and J. Stephan, "Fossil Fuel Subsidies in Lebanon," Ministry of Environment, Beirut, 2015.

[36] D. v. Amelsfort and V. Swedish, "Introduction to Congestion Charging," GIZ, Bonn, 2015.

[37] "LEZ Strategic Review Report," Deloitte.

[38] J. Ekstrom, "Designing Urban Road Congestion Charging Systems - Models and Heuristic Solution Approaches," Link¨oping University, Norrk¨oping, 2008.

[39] D. v. Amelsofrt, "Congestion Charging," International Energy Agency, 2015.

[40] W. Marrouch and J. Mourad, "Effect of Gasoline Prices on Car Fuel Efficiency: Evidence from Lebanon," in *First Energy Economics Conference*, Beirut, 2018.

[41] "Lebanon's Nationally Determined Contribution Updated 2020 Version," Ministry of Environment, Beirut, 2020.

[42] D. Pojani and D. Stead, The Urban Transport Crisis in Emerging Economies, Switzerland: Springer, 2017.

[43] S. Kearns, "International Best Practices for Congestion Charge and Low Emissions Zone," Energy Foundation, Beijing , 2014.