RESILIENCE OF URBAN MOBILITY IN THE FACE OF FOSSIL FUEL DEPENDENCY

AN EMPIRICAL STUDY OF RIO DE JANEIRO

Dissertation

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DECLARATION

I hereby declare that I alone wrote the doctoral work submitted here under the title **"The Resilience of Urban Mobility in the Face of Fossil Fuel Dependency: An Empirical Study of Rio de Janeiro"**, that I only used the sources and materials cited in the work, and that all citations, whether word for word or paraphrased are given as such. I declare that I adhere to the guidelines set forth by the University of Tübingen to guarantee proper academic scholarship (Senate Resolution 25/05/2000). I declare that these statements are true and that I am concealing nothing. I understand that any false statements can be punished with jail of up to three years or a financial penalty.

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ABSTRACT

Long-term scenarios for mobility within cities usually neglect the challenge of energy supply and the ways in which the implied risks can affect urban mobility services. High levels of private transport and fossil fuel dependency tend to prevail in urban agglomerations of modern cities in many parts of the world. The concept of resilient mobility supports a new perspective of transportation solutions, based not only on questions, like how less energy can be consumed or how less CO_2 can be emitted, but how vulnerable urban mobility is, in the light of fossil fuel dependency, in case there is a sharp increase of the oil price or even a supply disruption. There are factors within the social and geographical scope, which help understand mobility patterns and possible impacts in case there is a fossil fuel supply threat. The analysis of these additional factors can lead to new policy and planning approaches.

This thesis integrates the resilience concept into the urban mobility research field, through a diversified literature review, generating a conceptual framework on the resilience of urban mobility. Furthermore, quantitative and qualitative methods are developed, based on a proposed framework concerning resilience of urban mobility and applied to the city of Rio de Janeiro.

The developed and applied methodologies involves the evaluation of the resilience of urban mobility based on a process divided in three stages, the capacity to persist, ability to adapt and the potential to transform the city, in order to be resilient, when confronted with a fossil fuel threat.

The quantitative method is based on a social-centered approach, which is evaluated whether the working population of the city of Rio de Janeiro possesses sufficient conditions to resist to fossil fuel threats, based on the urban and social characteristics of the city. This methodology confronts mobility options, geographical constraints and financial conditions of inhabitants.

The qualitative method consists in gathering information regarding the attitude of inhabitants of the city, regarding the current mobility patterns and possible reactions in the face of fossil fuel threats. Furthermore, the qualitative approach consisted, also, in evaluating policies and projects oriented to electric-based transportation solutions and the impact of social movements in improving urban mobility.

Results of this research highlighted the most and less resilient areas of the city of Rio de Janeiro. The areas with lower levels of resilience of urban mobility, are located in the north and west part

of the city. The areas with higher levels of resilience are located in the east and south part of the city, including the Central Business District and its surrounding area.

In order of Rio de Janeiro's social and spatial differences, the results showed that there are different combinations of problems for each part of the city, which generate vulnerable conditions for urban mobility being dependent on fossil fuels. It was observed that there is a high concentration of job positions in the district of Centro (the main distric of the Central Business District), along with higher wage levels in the districts geographically close to this area. In addition to this, there is an electricity-based transportation system, which has a limited geographical reach and a limited carrying capacity, leading to an intensive use of oil-based public and private transportation.

Beyond these problems, it was identified that there is an attitude issue regarding public transportation. In other words, it is likely, that users of public transportation tend to see the public transportation system as an uncomfortable obligation, because of the insecurity, lack of money to use private transportation, dependency on conventional bus and Bus Rapid Transit (BRT) systems (oil-based), high costs involved in travelling, long distance to work, etc.

It has been observed in this research that even in areas of the city that already have an acceptable level of accessibility to train or metro systems, a significant part of the respondents (sample of the qualitative method) are willing to change their modal choice, as they are faced with extreme fossil fuel threats, even if it affects personal expenses.

The city is divided between those who can afford living close to work, those who can afford private transportation and those who cannot afford either of these two options. This third group is, in significant numbers, located in areas of the city that have had long been receiving less investments in the private and public sectors, leading to a complex mixture of urban problems, from low quality of transportation services, education, medical care, security, basic sanitation, etc.

The challenge of the city of Rio de Janeiro goes beyond improving transportation infrastructure to reach the same places because the capacity of the system is limited. It also needs to improve basic infrastructure and urban services in vulnerable areas, attracting the private sector to these areas, consequently reducing travel distances to work, transportation costs and improving urban mobility.

ZUSAMMENFASSUNG

Langfristig orientierte Mobilitätsszenarien für Städte vernachlässigen in der Regel den Aspekt der Energieversorgung sowie die damit implizit verbundene Vulnerabilität urbaner Mobilitätssysteme. Im Agglomerationsraum moderner Städte überwiegt typischerweise ein hoher Anteil privaten Personenverkehrs bei zeitgleich hoher Erdölabhängigkeit des urbanen Mobilitätssystems. Das Konzept der Resilienz bzw. der resilienten Mobilität bietet eine innovative Perspektive auf städtischen Personenverkehr, die sich nicht auf Fragen von Einsparungs- und Reduktionspotenzialen in Konsumverhalten oder CO_2-Emissionen beschränkt, sondern vielmehr die Vulnerabilität (Anfälligkeit; Verletzlichkeit) urbaner Mobilität im Kontext ihrer Abhängigkeit von Fossiler Energie beleuchtet.

Zur Erforschung des möglichen Impacts von Versorgungsengpässen und Preisschwankungen auf urbane Mobilitätssysteme einschließlich des individuellen Mobilitätsverhaltens wird ein Set an sozialräumlichen Einflussfaktoren herangezogen. Die Analyse dieser bislang wenig berücksichtigten Faktoren stellt neue konzeptuelle Zugänge für (Stadt) Politik und Planung in Aussicht. Die Arbeit trianguliert das Konzept der Resilienz mit dem Forschungsfeld "Urbane Mobilität" mittels einer breit gefächerten Literaturanalyse und entwickelt aus diesem theoretischen Fundus eine Heuristik für eine "Resilienz urbaner Mobilität". Dabei werden quantitative und qualitative Methoden erarbeitet und auf das Fallbeispiel Rio de Janeiro angewendet.

Rio de Janeiro zeichnet sich durch eine hohe sozialräumliche Differenzierung aus. Es zeigt sich, dass jeweils verschiedene Sets an Problemfaktoren und -konstellationen für unterschiedliche Stadtteile vorliegen, die qualitativ und quantitativ unterschiedliche Vulnerabilitäten der urbanen Mobilität in Bezug auf Fossile Energie verursachen. So sind im Central Business District Rios (Centro) und den umliegenden Stadtbezirken die Arbeitsplatzdichte und die Gehälter am höchsten. Es besteht ein elektrisches ÖPNV-System mit begrenzter geographischer Reichweite und Aufnahmekapazität, was eine intensive Nutzung privater und öffentlicher erdölbasierter Mobilität begünstigt. Jenseits dieser Problematiken wurden Einstellungs- und Nutzungskonflikte gegenüber den öffentlichen Mobilitätsangeboten identifiziert: ÖPNV-Nutzer empfinden das öffentliche Verkehrsangebot als unsicher, stigmatisieren es als nachrangig gegenüber privater Mobilität und empfinden sich als abhängig von Bussen und Bus Rapid Transit-Systemen (erdölbasiert). Hohe Mobilitätskosten sowie lange Pendelstrecken sind weitere Problemfaktoren. Es wurde beobachtet, dass sogar in Stadtgebieten mit guter Erreichbarkeit von Zug- und Metronetzen ein signifikanter

Teil der Befragten (qualitative Stichprobe) bereit ist, die eigene Verkehrsmittelwahl (modal choice) anzupassen, wenn z.B. Versorgungsengpässe oder signifikante Preisanstiege vorliegen, auch wenn dies die eigenen Ausgaben erhöht. Rio de Janeiro ist geteilt in jene, die sich einen Wohnraum in Arbeitsplatznähe leisten können, jene, die die Mittel für das Pendeln zum Arbeitsplatz aufwenden können und solche, die sich keine von beiden Optionen leisten können. Diese dritte Gruppe wohnt in signifikanter Anzahl in Stadtgebieten mit Investitionsstau im öffentlichen wie privaten Sektor, was zu einem Konglomerat an problembehafteten Zuständen führt: von niedriger Qualität des lokalen Mobilitätsangebots, über schlechte Infrastrukturen in den Bereichen Bildung, medizinischer Versorgung, Sicherheit, bis hin zu mangelnder sanitärer Grundausstattung. Die Herausforderung der Stadt Rio de Janeiros reicht über die Aufwertung des bestehenden Verkehrssystems hinaus, weil dessen Kapazitäten begrenzt sind. Es bedarf zeitgleich der Aufwertung basaler Infrastrukturen und Dienstleistungsangebote in vulnerablen Stadtgebieten, um gezielt Investitionen in diese Bezirke zu lenken, Pendelstrecken zu verkürzen, Mobilitätskosten zu reduzieren und im Allgemeinen die urbane Mobilität aufzuwerten.

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Table of Contents

TABLES:

Figures:

CHAPTER 1

1. INDTRODUCTION

1.1. Background and Motivation

The world urban population has surpassed 50% and according to the United Nations (UN) (2015), this number may reach 66% by 2050. To face the increasing urban problems that haunt cities in the world, regarding social, economic and environmental aspects, effective solutions need to be developed.

Because of the growing concerns regarding the impact of the growing cities on the availability of natural resources, climate change and quality of life, this research pursues to focus on the urban mobility issues, concerning the fossil fuel dependency. Even though there are many efforts to improve the transportation sector in cities, urban populations are growing at the same pace as environmental concerns. There are challenges regarding the growing demand on mobility improvements and on the environmental effects generated by this sector.

This research aims to address the mobility issues from the perspective of resilience, with the intention of focussing on the urban mobility to face shock situations, such as price increase or reduction in fossil fuel availability. It is known that these types of situations can be caused by natural or anthropogenic events. Most literature on sustainable solutions has been approaching mobility issues under the argument of reducing the emission of greenhouse gases to reduce its effects on climate change. These solutions vary from improving technologies of fuel consumption, to stimulating the creation of compact cities, reducing the distance to the workplace and encouraging walking and cycling trips.

This research pursues to understand whether the urban mobility solutions represent a “real” transition regarding fossil fuel dependency or they are still postponing the problem, which, the mobility sector being dependent on limited resources, can also have an increase in price, generating an “uncomfortable” situation, regarding the availability of financial resources to maintain urban mobility conditions.

Currently, what concerns people is not the existence and growth of urban areas, but how much the urban environment consumes non-renewable resources. Consequently, the concern is how much the cities are vulnerable to this dependency.

As some cities of the world exceeded one million in terms of population (at the end of the 19th century), sectors of the society (e.g. NGOs, Governments, private sector, citizens, etc.) started to show some concern regarding urban quality of life. This period was represented by explosive urban growth, strong migration tendency to the urban centres, industrialisation, mechanisation, reorganisation of urban environments and political movements (Harvey, 2012, pp. 33-34) and the cities started to deal with more stronger and concentrated economic, social and environmental crisis.

In the 20th century, cities of the world have continued to grow, but there have been events that affected the cities' general conditions. Without considering both world wars, it is relevant to consider the great depression of 1929 and the oil crises of 1973 and1979. The great depression was quite challenging for cities, considering that the financial capital of the world was integrated and it concentrated a relevant quantity of investment, which was responsible for growing markets in different scales and consequently generating jobs and influencing social patterns. These crises generated high rates of unemployment in cities, leading the urban population, mainly middle and lower classes, to claim better wages and life conditions. The oil crisis of 1973 in order of the oil embargo from the Organization of the Petroleum Exporting Countries (OPEC) affected cities of the world. This event increased the price of oil, consequently affecting mobility within cities that built their spaces favouring individual transportation (Parish, 2009; Mogridge, 1978).

This research addresses the relationship between the fossil fuel crisis and urban mobility, mainly because it is not often found in a research, which directly relates these elements. It is much more common to find the effects of energy crisis in economic aspects. There is a need for cities dependent on fossil fuels to increase their resilience, not only by reallocating investment to control the oil price, but preventing the other ways in which fossil fuels can affect cities, such as its depletion or occurrence of natural disasters (floods, hurricanes or earthquakes), which will interfere in the supply of these resources to cities.

Aiming on the urban scale, there are elements that have influence over the relation between the cities and its dependency on fossil fuels. Urban mobility is one of these elements that can make a city vulnerable to the fossil fuel crisis, depending on the type of transportations pattern and land-use aspects (Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009).

It is unquestionable that the world still is, mostly, dependent on fossil fuels. According to OECD (Organization for Economic Co-operation and Development), in 2011, it was measured that approximately 81% of the primary energy consumed in the world is from fossil fuels. This consumption has been around 80% since 1990 (World Bank, 2015b). Although for some people the sustainable issue does not seem new anymore, the idea has not yet achieved a global concern, considering that one of the main objectives of those who really want to reduce the anthropogenic impact over the climate change is to reduce the emission of greenhouse gases due to the use of fossil fuels.

Energy plays an important role in the functioning of all the sectors in a country, such as transport, social development, heating, food, quality of life and military force (Brito, dos Santos, Chaigneau, & Nava, 2012). In the 21st century, the concern with issues related to energy security is increasing, because of a possible future exhaustion of fossil fuel resources, geopolitics instability and natural disasters.

To add on to this introduction, there is a global concern to improve urban mobility issues, not only over the point of view of improving the movement of people (considering only temporal and economic issues), but also environmental and social issues.

There is the C40 Cities Climate Leadership Group (C40)[1], which is committed to implementing meaningful and sustainable climate-related actions locally that will help address climate change globally (C40, 2014). There are currently 69 cities in the world that are part of this group, located in Africa, East Asia, Europe, Latin America, North America, South and West Asia and Southeast Asia and Oceania. Amongst the many issues addressed by this group, such as energy efficiency, sustainable communities, buildings energy efficiency, solid waste management and lighting, there is also the issue of mobility.

[1] http://www.c40.org/

Another example is EUROCITIES[2], which is a network of major European cities. Through six thematic forums, a wide range of working groups, projects, activities and events, they offer members a platform for sharing knowledge and exchanging ideas. The main topics discussed in this group are culture, economy, environment, knowledge society, mobility, social affairs and cooperation. The objective of this group is not only to discuss common issues that affect the day-to-day lives of Europeans, but also to "reinforce the important role that local governments should play in a multilevel governance structure. We aim to shape the opinions of Brussels stakeholders and ultimately shift the focus of EU legislation in a way which allows city governments to tackle strategic challenges at local level" (EUROCITIES, 2014). Concerning mobility issues, the Mobility Forum of EUROCITIES presents some priorities for improving urban mobility issues in major cities of Europe, presented in the Transport White Paper[3], which involves topics such as finance and fundings of urban mobility solutions, and generate a smart urban mobility, more connected and inclusive.

There is also the global network, Cities for Mobility[4], which promotes transnational cooperation between local governments, transportation companies, businesses, science and the civil society, with the aim of supporting the development of sustainable and efficient transport systems in the member cities (Cities for Mobility, 2014). According to their, there are already 550 members from more than 76 countries that participate in the Cities for Mobility.

The purpose of this work is to understand the connection between the issues related to fossil fuel dependency and mobility within cities. Towards a search for a way to measure the resilience of urban mobility facing fossil fuel dependency, the following situations need to be considered: increase of this resource price and possible reduction of its availability in the environment.

[2] http://www.eurocities.eu/

[3] http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm

[4] http://www.cities-for-mobility.net/index.php/about-cities-for-mobility/our-mission

1.2. Research Design

21st century has been a critical moment in terms of spatiality and its theoretical approaches (Carlos, 2011). This is because there has not yet been a theoretical perspective, which can support the full comprehension of what is to come, in relation to the growing concerns in the social, economic and environmental aspects, and the relationship of these aspects with geography.

This research for this thesis is conducted within the transport field, specifically in the urban environment, and more specifically, regarding the physical mobility of people. The research aims at understanding the existing literature on the topic and the historical perspective on the objects of study, which are fossil fuels, transportation, mobility and society. Through the comprehension of concepts related to resilience of the urban mobility and the historical perspective of the objects of study, the conditions to conceptualise the resilience of urban mobility are created. From this point of view, the initial part of this research can even be assimilated to the critical realism perspective, which intends to understand reality, rather than assuming the notion of reality (Tate & Kitchin, 2013; Psillos, 2011; Yeung, 1997; Carter & New, 2005).

According to Carter and New (2005), a realist scientific perspective starts with a description of the object of study, which in this research is represented by a review of the development of urban mobility, contextualising the role of fossil fuels in this development. Based on the historical description of the development of urban mobility and its relationship with fossil fuels, a concept and framework of resilient mobility is built. Furthermore, the challenge is to build a method to measure the resilience of urban mobility and to test this method through hypothetical threat scenarios, considering possible fossil fuel price increase or supply interruption of this resouce. From this phase of the research head, there can be a turning point because the creation of a concept may deal with other theoretical perspectives. However, the notion of realism supports exploring of other fields and organising the research structure.

Figure 1 presents the research design, built as a process. This process is divided into phases, starting from the contextualisation of the research problem, followed by an extensive literature review. The first two stages support the development of the framework and concept of resilience of urban mobility.

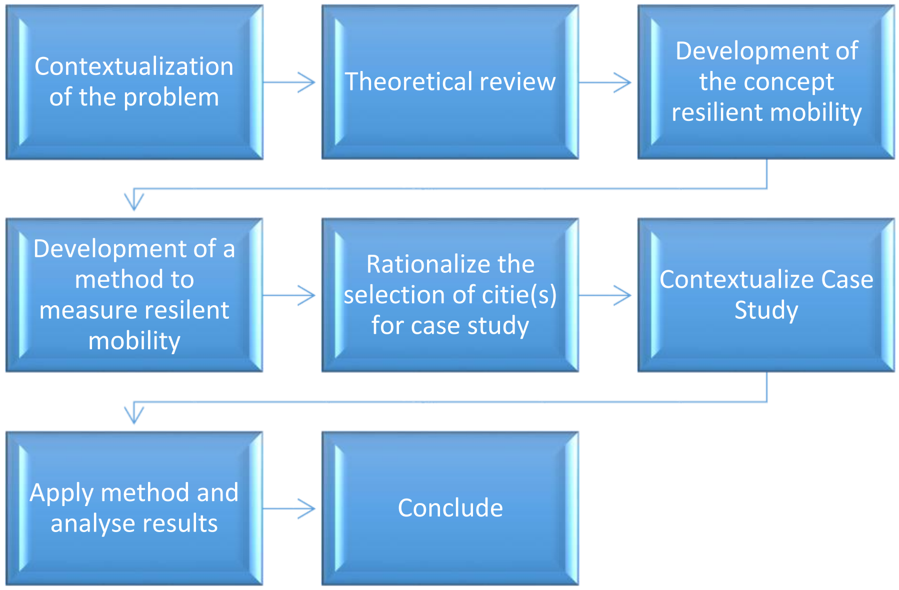


Figure 1: Methodological framework for the research

This research is not ultimately realistic (in theoretical notion), as the author is just acknowledging the support of this perspective to explore the topic of study in other fields, thereby contributing to a broader notion of urban mobility and its role on the production of urban space.

One can ask how realism could/did help in the construction of the thesis. The answer is that the approach of realism research seeks to identify the causal mechanism, in other words, what makes a structure vulnerable (Carter & New, 2005). The way in which a realist reaches this goal is to understand the precursors of an action and the action itself (Carter & New, 2005).

In the case of urban mobility, it is understood that men build the mobility in cities today and therefore, there is a historical logic of the urban mobility. According to this logic, the structure built is vulnerable and hence, the vulnerability of urban mobility can be seen as the action itself. The whole building process of the urban mobility is the precursor of the action. The understanding and interpretation of this process will allow a definition of a resilient mobility concept, faced with the objects of study, which are urban mobility and fossil fuels. Subsequently, an empirical test is conducted (involving qualitative and quantitative research), based on the inductive conceptualisation of the resiliency of urban mobility.

1.3. Objectives of the Research

This thesis intends to investigate the impacts of fossil fuel crises over urban mobility. By following the latest news and academic studies, it is possible to observe that when urban mobility is in jeopardy, there can be social (Dantas, 2015) and economic (Vasconcellos E. A., 2014b) consequences. Based on a geographical approach, this research questions the capability of cities to resist the fossil fuel crisis, analysing whether they are prepared to deal with the less availability of this resource or price increase.

The scale of this research is limited to the urban space. Within this scale, there is a search for vulnerable elements of the urban mobility, faced with fossil fuel dependency. Under this condition, some main goals for this research with the intention to find a way to measure the resilience of urban mobility were elaborated.

The specific objectives of this research are as follows:

- Contextualise historically the fossil fuels' use in urban mobility and the impacts of transportation on urban development;
- Define the concept of resilience of urban mobility. The definition of this concept will give support for the next step, which is finding a method to measure the resilience of urban mobility confronting fossil fuel crisis;
- Determine a method to measure the resilience of urban mobility through a literature review and analysis of the methods related to resilience within the urban environment. The method to measure the resilience of the urban mobility system is determined based on the defined concept in this thesis and on the elements that are linked with it;
- Review and characterise the city that can be used, possibly, as the case study for this research;
- Collect data for the urban mobility resilience measure, for the case study. Then apply the resilience measure, based on the determined method;
- Review urban planning policies in the selected city for the case study, regarding elements that bring benefits to mobility issues. Evaluate if the policies that are not yet applied will enhance urban mobility resilience;

- Evaluate the importance of the research, through an overview of the applied method and reached results.

1.4. Questions, Hypothesis and Provocations

This research aims at building a resilience concept of urban mobility. It is argued that in the previous approaches to sustainable transport, elements of social interrelations and meanings are underrepresented. This may result in policy consequences in case of a sudden fuel price increase or disruption of oil supply.

The motivation of this research is grounded on the lack of discussion regarding the resilience of urban mobility, faced with fossil fuel dependency. This context rose some initial questions, such as what elements of the social and built environment are vulnerable to sudden external threats, such as increase of fuel price or availability reduction of fossil fuels?; how can the resilience of urban mobility be conceptualised? The first step is to understand the current context in relation to sustainability, climate change, energy and transportation.

The Intergovernmental Panel of Climate Change (IPCC, 2014)reported that the global temperature has already increased by 0.85°C since the beginning of industrialisation. Even if CO_2 is not being emitted, it is already predicted that this temperature growth can reach 1.5°C. Furthermore, IPCC affirms that the heat island process in cities can present a 10% increase over the average global temperature increase. Besides the climate change issues, there is constant population growth in the urban areas. This creates even more challenges with regard to the movement of people within the city and how this can be managed, bringing together social equity and environmental commitment.

Since the 1970s, the concept of sustainable development has been introduced to virtually all sectors of the public and private economy. However, global consumption of fossil fuels has not decreased, but increased from 80% (1992) to 81% (2012), with respect to the total primary energy consumption in the world (World Bank, 2014).

One third of the global energy consumption and 61% consumption of the global petroleum are caused by the transportation sector. Furthermore, approximately 95% of the energy consumed in road transportation (at global scale) is oil-based (Rodrigue, Comtois, & Slack, 2013).

Future scenarios do not seem favourable for cities regarding mobility. High levels of private transport and fossil fuel use will prevail. A concept of resilient mobility will support a new perspective of transportation solutions, not only based on questions like how less energy can be consumed or how less CO_2 can be emitted, but how vulnerable urban mobility is faced with fossil fuel dependency, in case there is a price increase of oil or even a supply disruption.

The idea of a resilient mobility does not reduce the importance of sustainability approaches but complements it in order to support a transition in urban mobility facing the peak of global oil production in this century (Hirsch, Bezdek, & Wendling, 2005). Under this context, some research questions were built, born from the initial thought and readings on the topic, these questions can also be read as hypotheses, when turned into affirmations:

1. How important are fossil fuels in today's society?
2. What is the relationship between urban mobility and fossil fuels?
3. Is there an existing solid concept on the resilience of urban mobility?
4. If there is no solid existent concept, how to conceptualise it?
5. What elements of society are involved in the resilience of urban mobility?
6. What is the difference between resilience of urban mobility to sustainable mobility and energy security?
7. How can the resilience of urban mobility be measured, faced with fossil fuel threats?
8. How can the resilience of urban mobility be classified in levels?
9. Is it possible to predict the resilience of urban mobility, faced with hypothetical scenarios of fossil fuel threats?
10. Is it possible to predict the resilience of urban mobility, based on improvements, which will be implemented in the future?
11. What are the benefits for a city, when approaching the resilience of urban mobility?

1.5. Thesis Outline

This thesis is divided into 10 chapters and the content of each chapter is described in the following points:

- ***Chapter 1***: This chapter introduces the thesis, focussing on the motivation and background to choose the resilience of the urban mobility topic. Furthermore, it presents the design of the research, showing the stages of the work. Besides this information, it presents the objective of the thesis and open questions to be answered along with the research.

- ***Chapter 2***: This chapter focusses on establishing the relationship between cities and fossil fuels, through a historic and geographical perspective. Leading to a closer review on urban transportation systems because of its development, presents a development process closely related to the high consumption of fossil fuels.

- ***Chapter 3***: This chapter aims at the theoretical background, in order to build the concept of resilience of urban mobility. This chapter approaches this objective by reviewing the literature about urban mobility and transportation from various perspectives from different fields of research, such as geography of urban transportation, urban sociology and energy security.

- ***Chapter 4***: This chapter focusses on locating the built concept of resilience of urban mobility within the already established urban resilience concepts found in the literature review.

- ***Chapter 5***: This chapter addresses the difference between the concepts of resilience of urban mobility and sustainable mobility. Furthermore, it presents how these two concepts can complement each other.

- ***Chapter 6***: This chapter presents the methodology to evaluate the resilience of urban mobility, which is based on the framework of this concept presented in chapter 3. The methodology presented involves a qualitative and quantitative approach.

- ***Chapter 7***: This chapter explains the reason why the city of Rio de Janeiro is selected as the case study. Furthermore, it describes characteristics of the city from a social and economic perspective.

- ***Chapter 8***: This chapter presents the results about the resilience of urban mobility of the city of Rio de Janeiro, based on the procedures suggested in the chapter on methodology.

- ***Chapter 9:*** This chapter presents the conclusions, seeking to point out the final view of the results and to discuss whether the objectives of the thesis were attained. Furthermore, this chapter presents the limitations and further research intentions.

CHAPTER 2

2. THE RELATIONSHIP BETWEEN CITIES AND FOSSIL FUELS

This section intends to explore the fossil fuel issues within a world and urban context, in order to draw an overview of the relevance of this natural resource for humankind, pointing out significant changes in the industry and transportation sector. It also reviews the impact that evolution in transportation has brought to urban development and growth.

2.1. When, How and Why Fossil Fuels

Since the beginning of humankind, energy has been an important element for the overall development, from the hunter-gatherer societies and agrarian civilisations to modern industrialised civilisation (Heinberg, 2003; Schlör, Fischer, & Hake, 2012). There were different energy periods, which each had its own energy basis, therefore bringing different approaches towards the needs of human civilisations (Schlör, Fischer, & Hake, 2012).

During medieval times in Europe, the main energy source came from wood, in order of its utility and abundance at the time. It was used to build houses, produce weapons, build transportation, make useful tools (used in agriculture and other sectors), to cook, for lighting and heating (Heinberg, 2003). The intensive exploitation of wood led to social development and population increase, however, this generated wood shortages (Heinberg, 2003; Schlör, Fischer, & Hake, 2012). According to Schlör et al. (2012), the first sustainable systems occurred in the middle of the 14th century, when local German Feudalism developed environmental laws to protect their forest. However, the extensive exploitation of coal avoided a collapse at the time (Heinberg, 2003; Schlör, Fischer, & Hake, 2012).

In Europe, although coal was already a known resource and was being used for heating and cooking during medieval times, only the shortage of wood allowed a higher exploitation of coal. At that time, coal ("black stone") was regarded as an inferior fuel because it produced too much soot and smoke (Nef, 1977).

Despite the soot and smoke, the increase in the use of coal in the following centuries (15th, 16th, 17th, 18th and 19th) stimulated the finding of its advantages in manufacturing and metallurgic sectors (Gilbert & Perl, 2008; Nef, 1977). By the end of the 18th century, the high demand for coal encouraged the development of tracks made of cast-iron rail, which served stability to wagons, with traction supplied by horses, allowing higher weight capacity. By the beginning of the 19th century in England, railways had been implemented because of their superiority over horse-drawn rail carriages (Gilbert & Perl, 2008). In the middle of the 19th century, ships started to change the renewable human and wind power to steam power, thus improving time and weight capacity of the ships (Gilbert & Perl, 2008).

During the 19th century, when motorised machines proliferated, vegetable oil and whale oil were used for lubrication, and whale oil was used for lamps (Australian Government, 2013; Martin, 2001). Due to the increasing demand of whale oil, commercial whale species were hunted to the point of extinction and whale oil was becoming increasingly costly (Heinberg, 2003; Martin, 2001). With the beginning of drilling and refining petroleum, in the late 19th century, the problem with whale oil depletion was solved. The late 19th and early 20th centuries were also the periods of discovery and implementation of natural gas and electricity in the urban daily life, which contributed to the industrialised sectors and urban infrastructure.

The 20th century is known as the "petroleum era", because of the increasing application of this resource in transportation, agriculture, industry and warfare. In the transportation case, it is possible to affirm that automobile industry played a significant role in the US, between the 1920s and 1970s (Rodrigue, Comtois, & Slack, 2013; Hanson & Giuliano, 2004). Let us take the example of New York. The city had grown with the implementation of electric trolleybuses and streetcars in the beginning of the 20th century. However, the auto industries started to buy streetcars and trolleybus lines, and switched them to buses fuelled by diesel. Moreover, urban planning favoured the cars, along with the construction of bridges and highways (Rodrigue, Comtois, & Slack, 2013; Gilbert & Perl, 2008). According to Heinberg (2003), many cities of Europe responded to the automobile differently by investing more in trains, trolleys and subways. By the middle of 20th century, air transportation also started to move people around the world.

In the agricultural sector, the use of petroleum led to the development of synthetic chemicals derived from synthetic ammonia, petrochemical-based herbicides and pesticides. Moreover, there was the implementation of motorised equipment (Ross, 2013). These technical and chemical developments boosted the production of food in the world, also influencing the increase of population in cities.

In relation to the industry realm, all sectors from machinery, chemicals to goods grown with the discovery of the diverse petroleum applications went beyond lighting and heating. The 20^{th} century is also known for the both world wars, which stimulated the growth of the armoury industry, with the development of fossil-fuelled weapons having a high range and stronger effects (Heinberg, 2003; Ross, 2013).

From a historical perspective, it is noticed that the 20^{th} century was the beginning of the increased use of petroleum, initially in order to attend society's needs to increase industries' production, to optimise transportation and to improve daily urban life. It is also important to consider that scientific discoveries, as automobiles, new chemicals and types of refined petroleum, played a significant role in all sectors of the society, considering that these discoveries were improved and applied in the urban and rural environments along time.

2.2. Fossil Fuels Relevance in the World Context: Post World War II

After World War II, the consumption of petroleum increased worldwide, especially in the US and Europe. However, by the second half of 20^{th} century, US was not producing enough oil for its own consumption and started to depend on the outside oil market, especially on the Middle East oil production countries, such as Saudi Arabia, Iraq, Iran, Kuwait and United Arab Emirates (OPEC countries), where the first three have a higher production rate.

From a geopolitical perspective, the support of the US government to Israel resulted in severe consequences by 1973, when a coalition of Arab states led by Egypt and Syria crossed ceasefire lines to enter the Sinai Peninsula and Golan Heights, initiating the Yom Kippur War (Sagan, 1979). The Soviet Union was supporting the Arab states and the US was supporting Israel, which almost initiated a direct confrontation between the two superpowers. This possible confrontation was the reason to negotiate a cease-fire in the region. However, the ongoing aid of the US government to Israel influenced Arab states to break the agreement and impose an oil embargo against the US.

This embargo initially brought four months of long queues at the US gas stations. Besides that, the world oil price increased from \$3 to \$12 per barrel (Hopkins, 2008; Goldemberg, Johansson, Reddy, & Williams, 1987). Further, in 1979, war broke out again in the Middle East, between Iraq and Iran. Again, an artificial shortage of oil struck the world, with price of oil increasing from $12 to $30 per barrel (Goldemberg, Johansson, Reddy, & Williams, 1987). The increase in oil price affected the world economy. Moreover, the subsequent inflation increased the price of all goods, generating a whole chain reaction, affecting the day-to-day life of citizens around the world.

Despite the 1973 and 1979 oil crises, the oil price was maintained at a price lower than $30 per barrel (The Middle East Institute, 2009; IEA, 2015) in the last two decades of the 20th century. This was due to the following two reasons: discovery of new reserves, such as North Sea, off coasts of Nigeria, Angola, Mexico and North Slope of Alaska; and because of the maintenance of a good commercial relationship of the US with Saudi Arabia (Heinberg, 2003). Although, the intention of this thesis is not to explore war issues, it is important to point out an important debate. At the beginning of the 21st century (mainly after the 9/11 event), there was a wide range of discussions about whether the interference of the US government in the Middle East was to really to fight "terrorism" or their interest in the oil reserves.

Petroleum has turned into such a significant resource that any variation in its price can affect the world economy. This would consequently affect the agricultural and industrial sector, leading to an increase in the price of food and goods. Moreover, there is an impact on the transportation sector, considering that metropolises around the world are filled with cars and buses fuelled by gasoline and diesel.

By observing Figure 2, which shows the evolution of Brent and West Texas Intermediate (WTI) crude oil price (IEA, 2015), it is possible to observe that after the 1979 oil crisis, there was also a significant oil price increase in 1990 and 2008. According to Hamilton (2009) in 1990, the increase in the oil price was caused by Iraq's invasion of Kuwait in August 1990, which resulted in a dramatic and immediate disruption of the flow of oil from key global producers. The 2008 oil price increase could have been caused by a failure of physical production to increase at a demanding rate. Hamilton (2009) also points out the relationship between the GDP growth and oil price, and Figure 2 shows that between 2001 and 2008, the GDP growth increased until oil price jumped from, approximately, US$50 to almost US$140 per barrel, and simultaneously the GDP growth went negative. This fact can generate the assumption that oil price increase or decrease could be one of the factors related to GDP growth, even though, between the period of 2001 and 2007, the GDP rate had grown.

Identifying causes for any economic recession is often difficult (Kliesen, 2003) because it can be related to diverse things, such as consumers' spending pattern, real estate market, international trade, business investment and stock market. Observing Figure 2, the 2001 GDP growth decrease, considering that the previous argument (oil price increase) does not apply to this case, can be questioned because there was a GDP growth even with the oil price increase. The cause for the 2001 recession could be related to businesses and households' investment shocks. Moreover, there was the unexpected decline in export rates, which consequently affected the goods sector (Kliesen, 2003). According to Kliesen (2003), the 9/11 terrorist attack deepened what was previously in progress with the subsequent shut down of the financial markets and a significant part of the US transportation system for several days. Michael Moore's documentary, Fahrenheit 9/11 (2004), shows that after the US military occupation in Iraq, oil reserves in that region were exploited, which could have been one of the factors related to the growing GDP until 2007, despite the oil price increase. However, the hypothesis of a physical oil production failure in 2007/2008 seems to make sense, as it is an important factor for controlling the oil price, which can also be observed in Figure 3.

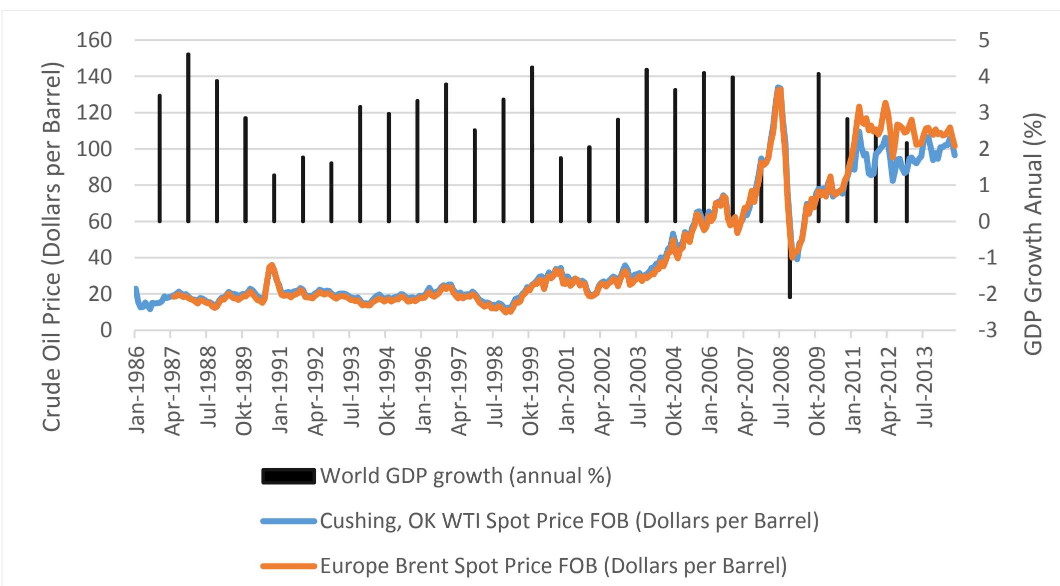


Figure 2: Crude Oil Price (Dollar per Barrel) (IEA, 2015) and GDP Annual Growth (%) (World Bank, 2015) – from January/1986 to August/2014

Figure 3 presents the information of the world crude oil consumption and supply. From this figure, it is possible to observe that from the beginning of the 1980s until 1990, oil consumption was slightly above oil supply, although the values are in the order of millions. In 1990, when consumption and supply seemed to be of equal value, the consumption increased and supply decreased again, coinciding with the 1990s oil crisis indicated previously in Figure 2. In between 2001 and 2003, the consumption increased and the supply decreased again, coinciding with the early 2000s recession. Between 2006 and 2008, the same event occurred with consumption and supply, coinciding with the 2008 oil price increase, followed by a negative world GDP growth.

The proved reserves of the world's crude oil are also included in Figure 3. When relating this data, roughly, with the daily production and supply of oil, it seems like there is a certain overall increase of proved reserves as consumption and production increases. However, there have also been periods of stagnation on proved reserve levels, as is observed between 1980 and 1987; 1990 and 2002; and 2003 and 2010. The periods of increase in proved oil reserves somewhat coincide (between stagnation periods) with a certain proximity of oil price increase and GDP decrease. This may be related to a possible forecasting of an oil supply shock, in the case that oil reserve levels increased before the oil price increase (the case of 1990), and a forecasting error in the case of an oil reserve level increased after an oil price increase (the case of 2001 and 2008).

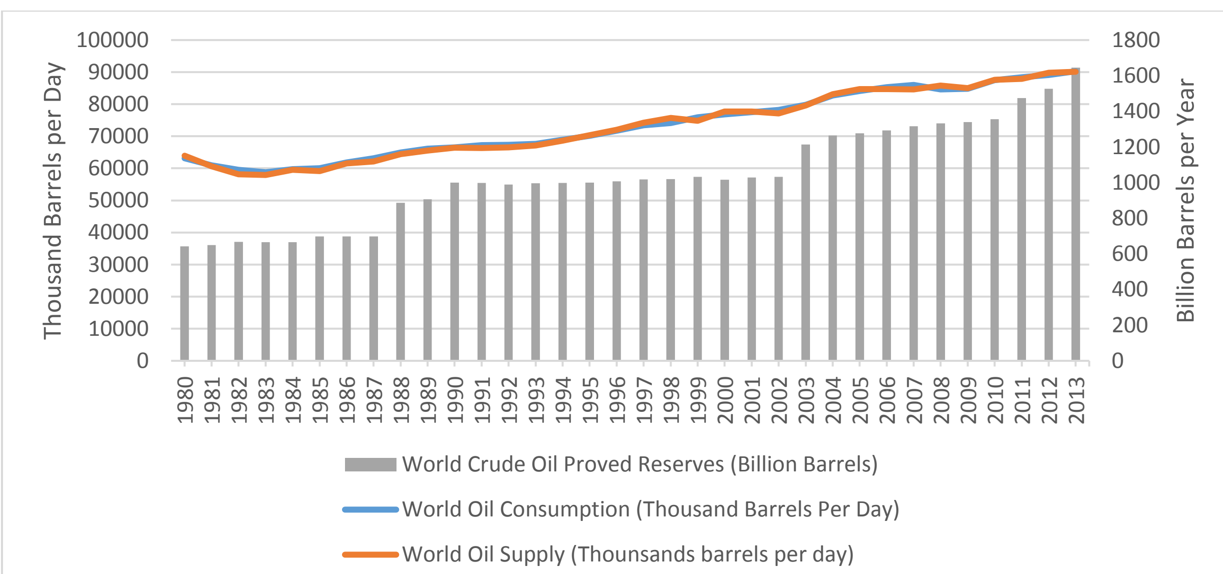


Figure 3: World Crude Oil Consumption and Supply; and Proved Reserves (IEA, International Energy Statistics , 2015)

As petroleum is not the only fossil fuel, Figure 4 was elaborated in order to visualise world consumption of fossil fuels, considering oil, natural gas and coal. From an overall analysis, it is possible to observe that there has been an increase in all fossil fuels' consumption, but the coal consumption is approximating to oil consumption. To get a better view of their increasing consumptions, the coefficient of variation was calculated (Figure 5), using the data of Figure 4.

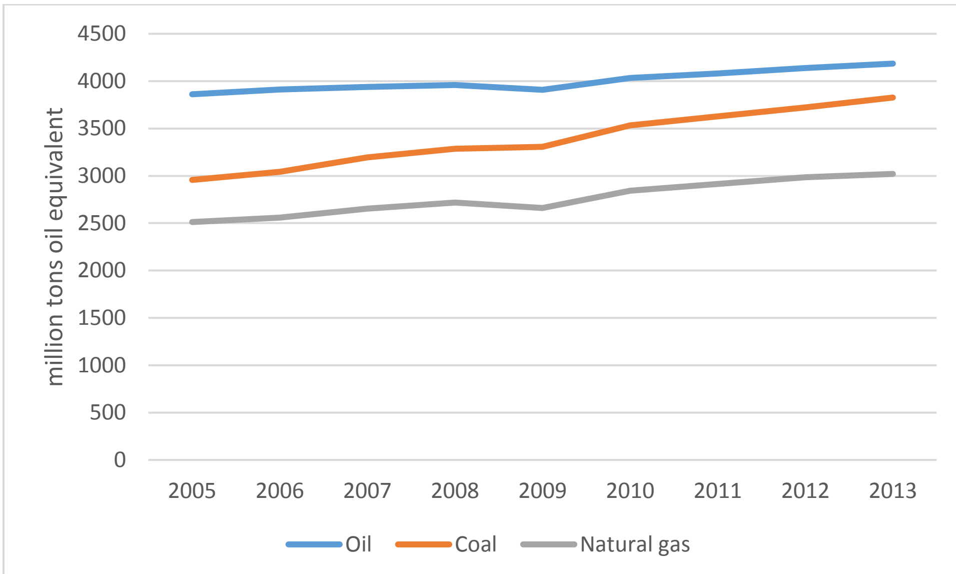


Figure 4: Fossil fuel consumption worldwide from 2005 to 2013, by fuel type (in million tons oil equivalent) (STATISTA, 2015)

By defining the ratio of the standard deviation to the mean, using data from Figure 4, the extent of variability in relation to the mean of each fossil fuel consumption is generated, whose result is presented in Figure 5. The results show that oil consumption has presented itself with the lowest variability and coal consumption with the highest variability, meaning that coal consumption is increasing at a higher rate than oil and natural gas. Is this scenario understandable? Which sectors of the society use which type of fossil fuels? This can be better explained by analysing the applications of each fossil fuel.

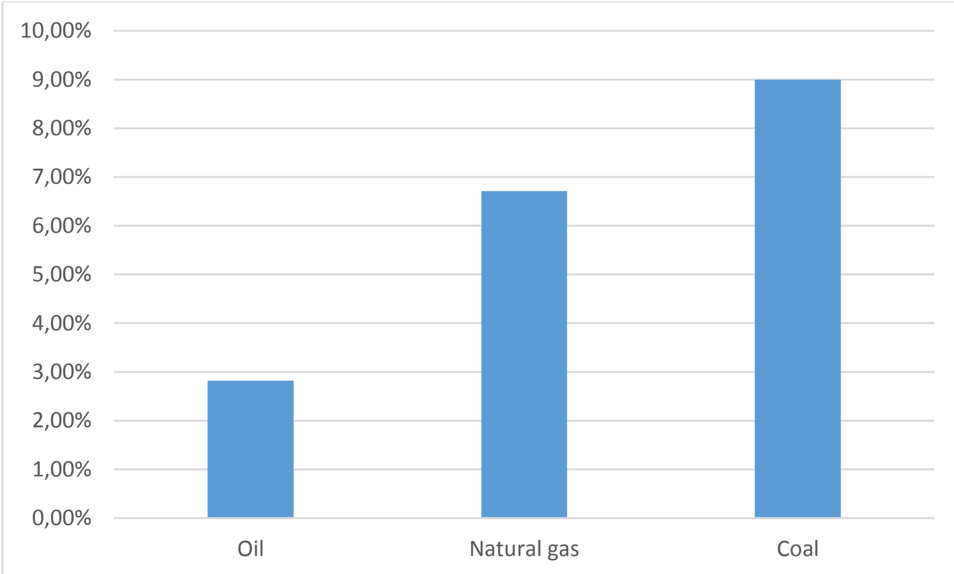


Figure 5: Coefficient of Variation of World Fossil Fuel Consumption (2005 - 2013) (STATISTA, 2015)

From a broader panorama, it is observed that fossil fuels occupy the biggest part of the global primary energy consumption (Figure 6). Observing that, in 2012, the fossil fuels were equivalent to, approximately, 87% of the global primary consumption, of which 33% is from oil, 30% coal and 24% natural gas. According to the World Bank, in 2011, the fossil fuels had a share of 81% in global primary energy consumption.

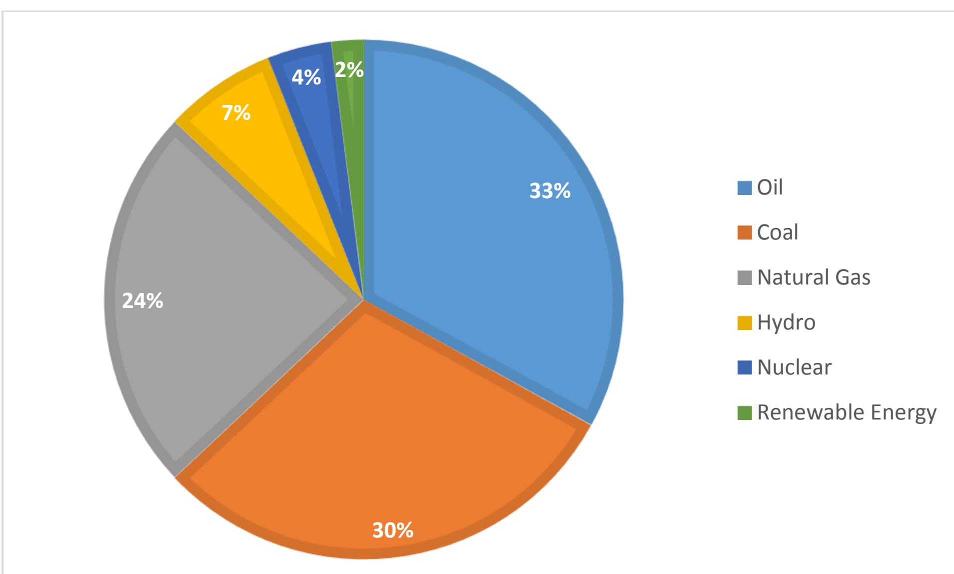


Figure 6: Global primary energy consumption in 2012 by fuel (BP, 2013)

When looking closely at the applications of each fossil fuel, it will be possible to observe, roughly, a level of dependency of each sector on each fossil fuel. Starting from oil consumption shares (Figure 7), the majority of oil consumption, in 2010, was allocated to transportation, which consumed 57%. Based on the OPEC World Oil Outlook of 2013 (OPEC, 2013), the transportation share will increase to 60% in 2035, while industry and others sectors will reduce by 3%, all together.

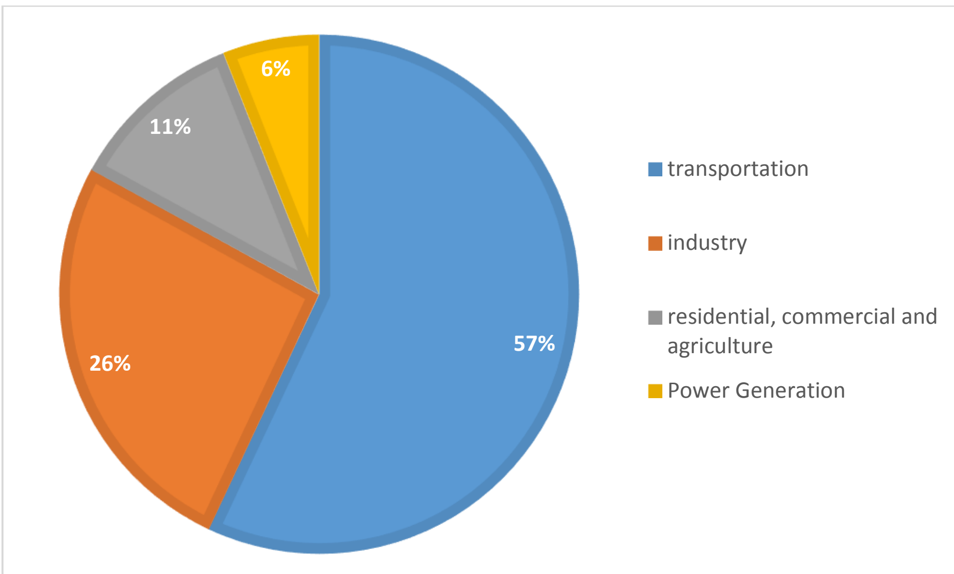


Figure 7: Percentage shares of oil Consumption by sector in 2010 (OPEC, 2013)

In the case of coal consumption share (Figure 8), it was measured that, in 2011, 60% of total coal consumption went to the electricity generation sector, while the other 40% went for the industry and for residential and commercial sector. The Institute of Energy Economics of Japan (IEEJ) predicts that by 2040, the share concerning electricity generation will reach, approximately, 70% of total consumption.

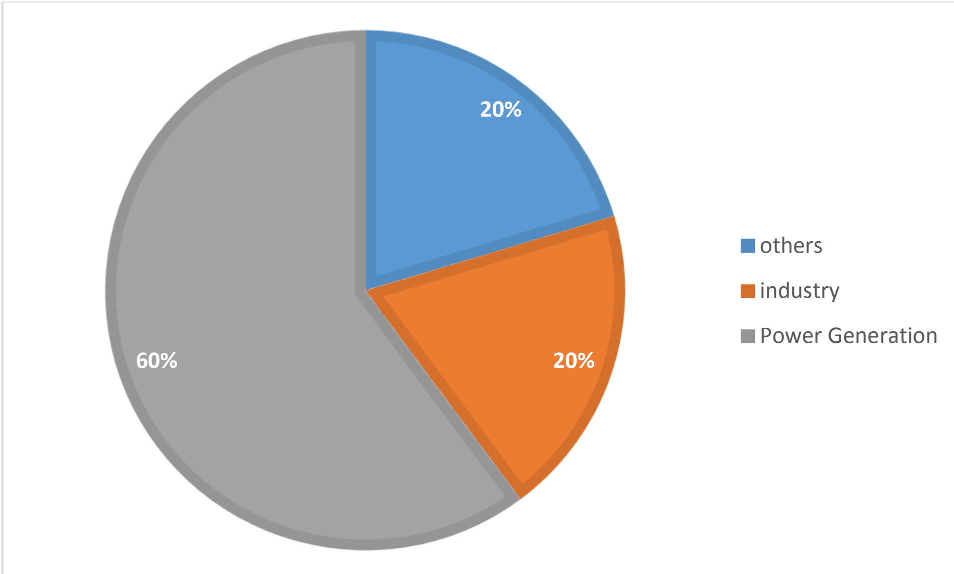


Figure 8: Percentage shares of Coal Consumption by sector in 2011 (IEEJ, 2013)

The measure found for the share consumption of natural gas (Figure 9) shows that 38% of total consumption concerns power generation. IEEJ predicts that by 2040 the power generation percentage will increase, approximately, to 40%.

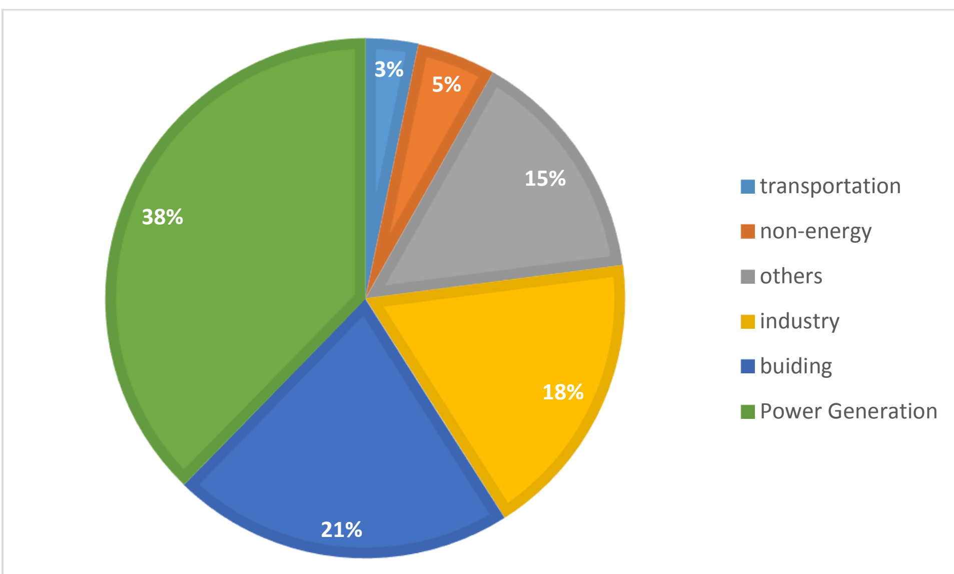


Figure 9: Percentage Shares of Natural Gas Consumption by Sector in 2011 (IEEJ, 2013)

The sectors which present higher dependency, based on the previous percentages (Figure 7, Figure 8 and Figure 9), are transportation, power generation and industrial sector. Although from an overall viewpoint, transportation seems to be a small part of the energy consumed, compared to power generation sector (Figure 10), looking from the use of renewable resources, it is the other way around, because, in 2009, "renewables accounted for 19.5% of global electricity generation and 3% of global energy consumption for road transport" (IEA, 2015). It can also be pointed out, in Figure 10, that although the growth of renewable resources and fossil fuel consumption can be predicted, fossil fuels still play a significant role in primary energy consumption, based on the prediction until 2035.

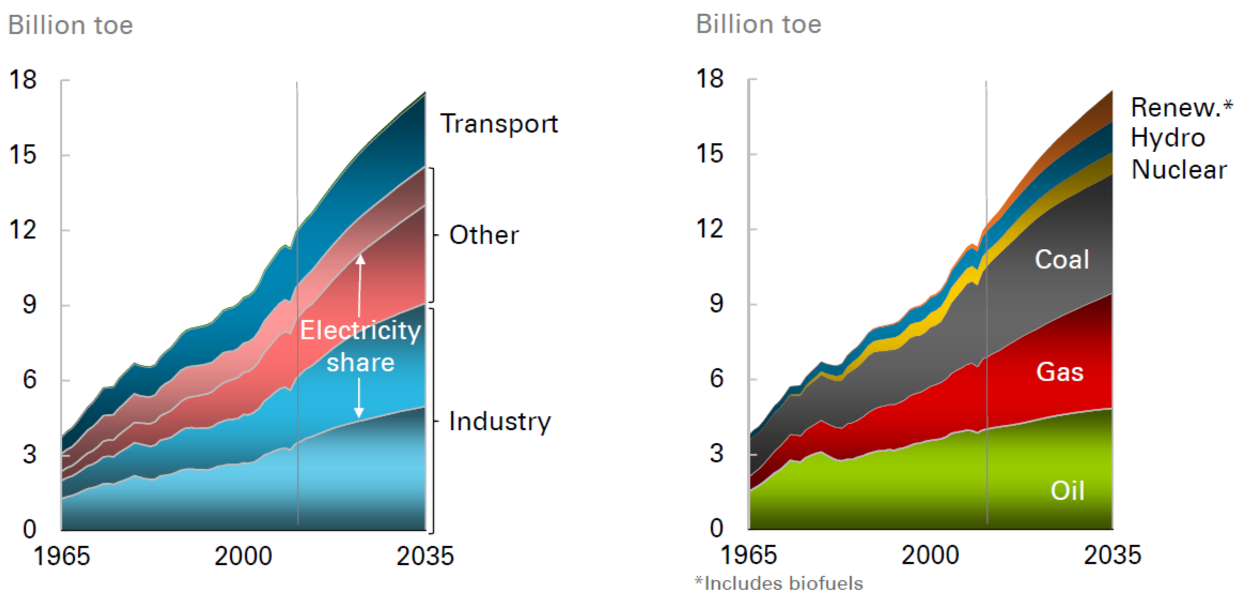


Figure 10: Total Energy Consumption by Sector and By Fuel (BP, 2014)

Concerning the industrial sector case, there is indeed a high dependency on fossil fuels; these resources play an important role on technological development (Hopkins, 2008). There are many products consumed today that are part of our daily life. According to Hopkins (2008), many things of everyday use are made with oil. They are as follows: aspirin, sticky tape, trainer shoes, lycra socks, glue, paints, varnish, foam mattresses, carpets, nylon, polyester, CDs, DVDs, plastic bottles, contact lenses, hair gel, brushes, toothbrushes, rubber gloves, electric sockets, plugs, shoe polish, furniture wax, computers, printers, candles, bags, coats, bubble wrap, bicycle pumps, fruit juice containers, credit cards, PVC windows, lipstick, etc.

However, a reduction in the dependency of fossil fuels in the industrial sector is dependent on the technological discoveries and recycling activities. The challenge is oriented to manufacturing products with less fossil fuels and learning to re-use recyclable waste.

The point is that the transportation and power generation are the most susceptible sectors to implement renewable resources as primary energy source, because there is an already-available technology that can reduce the dependency on fossil fuels. Furthermore, according to World Coal Association (2015), with the 2012 production rate and considering the proved reserves found until then, coal would last for 109 years more, natural gas for 56 years and oil for 53 years (Figure 11).

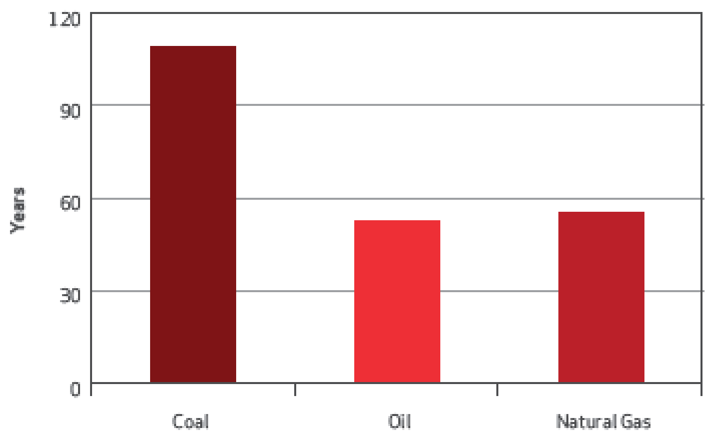


Figure 11: Fossil Fuels Reserves to Production Ratios at the end of 2012 (Years) (World Coal Association, 2015)

Although one can argue that proved reserves, today, may not be precise on the open media, and that approximately, "80% of world oil is controlled by national oil companies, who have no obligation to make their reserves data public" (Hopkins, 2008), oil can still be considered a limited resource. As this research brings the issue to a resilience approach, it is already possible to advance that when working with the resilience concept, uncertainties is an element, which plays an important role in the planning process (Jabareen, 2013). Even if Figure 11 presents a scenario that may not be entirely true today, it may become true sometime in the future. From this angle, it is worth considering this as a hypothetical scenario, as a starting point for further research. Therefore, regarding this presented scenario as true seems like oil is closer to collapse and is the most susceptible sector to suffer consequences is the transportation sector, which has a significant role on urban development today.

CHAPTER 3

3. THEORETICAL BACKGROUND: TOWARDS BUILDING A CONCEPT AND FRAMEWORK OF RESILIENT MOBILITY

Searching for the term “urban mobility resilience” and “resilience of urban mobility” (on July 30, 2014) in three web pages targeted to find academic material, “Google Scholar”, “Web of Science” and “ScienceDirect”, the search remained unsuccessful. Therefore, this chapter is dedicated to build a concept and a framework of resilient mobility.

Acknowledging the complexity of building a new concept, initially, this section aims to explore a variety of scientific fields, which addresses the transportation and mobility issues, such as transport geography, urban geography, urban sociology and energy security. This review seeks to gather information and find elements, which bonds and allows the definition of a concept of resilience of urban mobility, under a common scientific ground. The relationship of the selected elements allows the analysis of the vulnerability of the system, which supports the definition of the intended framework and concept.

The use of the term “mobility” instead of “transportation” can be questioned, leading to an “Urban Transportation Resilience” concept, for example. According to the Oxford Dictionary, the term “transportation” usually addresses the transportation system, regarding types of vehicles, network, capacity and demand. The intention is to understand the constraints under the social aspects, and the mobility that deals directly with the travel patterns of individuals, considering the available transportation system. For a quick comparison between the terms, “mobility” and “transportation” given in the Oxford Dictionary[5], look at the following:

- Transportation – “The action of transporting someone or something or the process of being transported”;
- Mobility – “The ability to move or be moved freely and easily”.

Through these brief definitions, it is possible to highlight that “mobility” is closely aligned with the objective of this thesis, which is to measure the resilience of mobility, faced with fossil fuel dependency, towards the understanding of how fossil fuel availability can affect the ability of

[5] http://www.oxforddictionaries.com/

people to move within the urban environment. The term “mobility” gives a sense of independency of people to choose how they are going to reach their destination, and the term “transportation” brings the interest directly to the transportation system, focussing on the vulnerabilities of the transportation system and not the individual.

Table 1: Definitions of Resilience related to mobility by author and field

Field	Author	Concept	Definition
Freight Transport	Adams et al. (2012)	Resilience of transportation network	“is the capacity to absorb the effects of a disruption and to quickly return to normal operating levels”
Gerontology	Wild et al. (2013)	Mobility resilience	“might refer to an individual’s personal mobility in terms of whether they are able to walk, whether they have a car, or whether they are physically fit, but also to broader environmental elements of mobility, such as whether there is an accessible high-quality public transport system or other forms of collective transport, whether a neighborhood has high ‘walkability’, or what road conditions are like and the degree to which a person feels safe to use them”

When searching for the terms “mobility resilience” and “resilient mobility” (on August 1, 2014), it was possible to realise that these terms are used in other research fields, such as freight transport (Adams, Bekkem, & Toledo-Durán, 2012), gerontology (Wild, Wiles, & Allen, 2013), wireless network (Li & Shen, 2014) and human behaviour studies (Gillespie, 2013). However, the definitions were found only in the first two fields cited (Table 1). Table 1 shows that resilient mobility has been built, however not specifying in which environment, location or scale. The first definition is aimed at the freight transport system and the second at the resilience of elderly people, considering physical and environmental aspects. Furthermore, the second definition from Table 1 (Wild, Wiles, & Allen, 2013) only supposes a definition.

To add, it was not easy to find mobility issues related to the resilient approach in academic materials, and none has been found linked to urban issues. This occurrence also serves as an argument that motivates the building of the resilient mobility concept, related to the urban environment and fossil fuel issues.

Considering only academic materials, the author of this research first found the word “resilience” in the book “Politics of Climate Change” by Anthony Giddens (2009). Giddens describes “resilience” as an adaptive capacity, the capacity, not only to resist an external change or shock, but also, whenever possible, to react to them in an active and positive way. It can be the characteristics of a physical environment, an individual or a group (Giddens, 2009).

According to Giddens (2009), the precursor of resilience studies are adaptation studies facing climate change. This means that initially, resilience studies focussed on environmental consequences caused by climate change. With time, this term has been adopted by other research fields for its multidisciplinary applicability (Giddens, 2009), and this current research brings this term for the urban mobility field.

The urban environment is well known for its complexity and for its several elements, which are interrelated and compose a city (Hoyle & Knowles, 1998). According to Pacione (2005, pp. 20-35), urban geography is linked with many other branches of geography, such as cultural geography, political geography, social geography, transport geography, etc. This thesis is developed under the transport geography perspective, acknowledging that there is a close relationship between urban transportation and urban structure (Pacione, 2005, pp. 264-281).

Another important aspect is the social distribution in space, which results from a selective history and geography, meaning that the social determination is a result of the necessities and possibilities in a determined moment in time (Santos, 1997, pp. 53-63). Pre-existent forms, bearers of functionalities, also determine social spatiality (Santos, 1997, pp. 53-63). Even though society is responsible for organising the spatial structure, this process occurs with mediation. This mediation can be considered as processes and its functions, leading to a social distribution pattern (Santos, 1997, pp. 53-63).

Based on Santos’ view of social spatial distribution (Santos, 1997), it can be considered that from the geography of the urban transportation perspective, the transportation system offered in a determined location may not be directly linked with the demand, because the offered system is planned and implemented by a mediator (e.g. municipality, transportation planners, etc.). Transportation planning does not often include the public. There are still barriers to a successful integration of public involvement in urban transportation planning, such as cultural aspects, in other words, the common top-down, one-way process, expert driven and techno-centric planning process (Booth & Richardson, 2001; Cascetta & Pagliara, 2013; Vasconcellos E. A., 2014a) and political barriers (Booth & Richardson, 2001). From this perspective, the social-spatial distribution can be conditioned by the transportation system; however, the social scale may not be taking part in the decision-making process.

Therefore, besides the relationship between transportation and urban structure, there are also the socio-spatial characteristics, which are conditioned to the transportation system and urban structure.

3.1. Geography of Urban Transportation: Background Focussed on the Mobility of People

The transportation system is responsible for allowing daily urban activities, which help people in obtaining medical care, education, leisure, having access to religious centres and cultural activities (Wachs, 2004). According to Rodrigue et al. (2013, pp. 42-87), transportation at the urban level represents the most significant spatial impacts at the local scale.

Regarding the purpose of transportation, it is aimed to overcome space, represented by distance, time, administrative division and topography and to fulfil a demand for mobility (Rodrigue, Comtois, & Slack, 2013, pp. 1-41). If people are not moving around, there is no sense for the existence of a transportation system; in other words, this system requires a derived demand, which can be direct or indirect (Rodrigue, Comtois, & Slack, 2013, pp. 1-41).

The direct derived demand is defined as the movements originated directly by the outcome of economic activities, such as work-related activities. As shown in Figure 12, in the work-related activity, "there is a supply of work in one location (residence) and a demand of the labor in another (workplace), transportation (commuting) being directly derived from this relationship" (Rodrigue, Comtois, & Slack, 2013, pp. 1-41) and considering physical constraints, when choosing a mode.

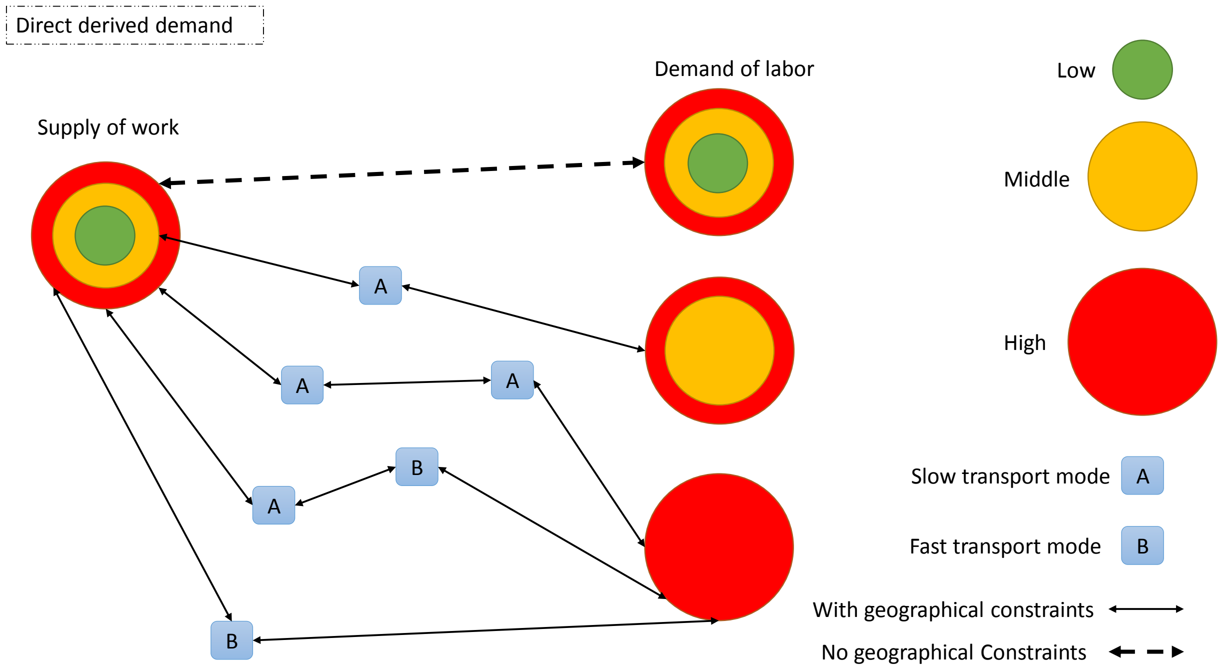


Figure 12: The effects of the direct derived demand on the transportation system (Source: adapted from Rodrigue et al. (2013, pp. 1-41))

The indirect derived demand is defined by the demand for the transportation system to keep working. In other words, it is related to the necessities of the transportation system regarding energy demand. As shown in Figure 13, "The fuel consumption from a transportation activities must be supplied by an energy production system requiring movements from zones of extraction, to refineries and storage facilities and finally, to places of consumption" (Rodrigue, Comtois, & Slack, 2013, pp. 1-41).

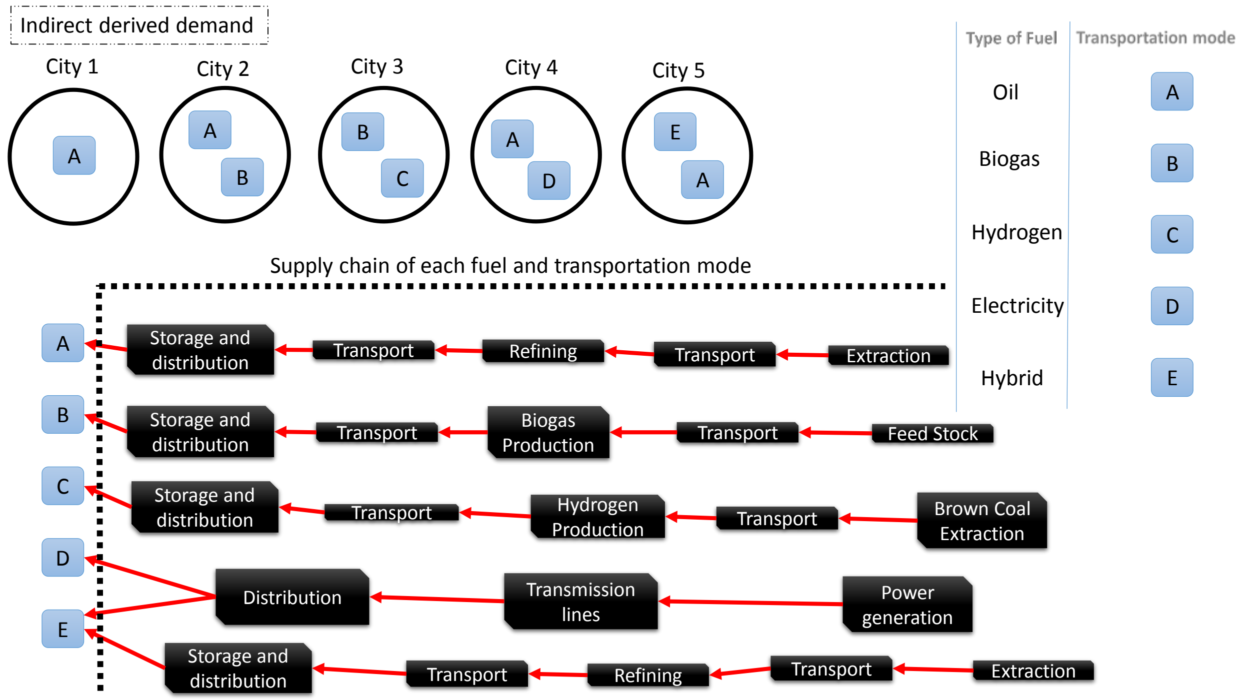


Figure 13: The effects of the indirect derived demand on the transportation system (Source: adapted from Rodrigue et al. (2013, pp. 1-41), Energy API (2015), Royal Institute of Technology (2012), Kawasaki Heavy Industry (2012) and ElectraNet (2015))

Based on the factor-based framework of the modern transport geography (Figure 14), it is possible to observe the complexity of the transportation system and the interdependence of factors that can be either affecting the system or being affected by the system. Hoyle and Knowles (1998) divide the factors in three steps of the transport interactive system (demand, provision and assessment).

As shown in Figure 14, these three steps constitute a cyclical process. The direct and indirect demand are the starting point to the provision step to attend the demand, which is composed by transport planning and implementation, considering socio-political, environmental, financial and technological factors. After the implementation, there is the assessment step, which is an evaluation of what has been implemented, considering usage characteristics, in a temporal and spatial scale, and affected factors (development, land use, environmental and throughflow changes). Following the last step, new demand conditions may be created and thus, new provision and new assessment are performed, considering previous positive and negative experience.

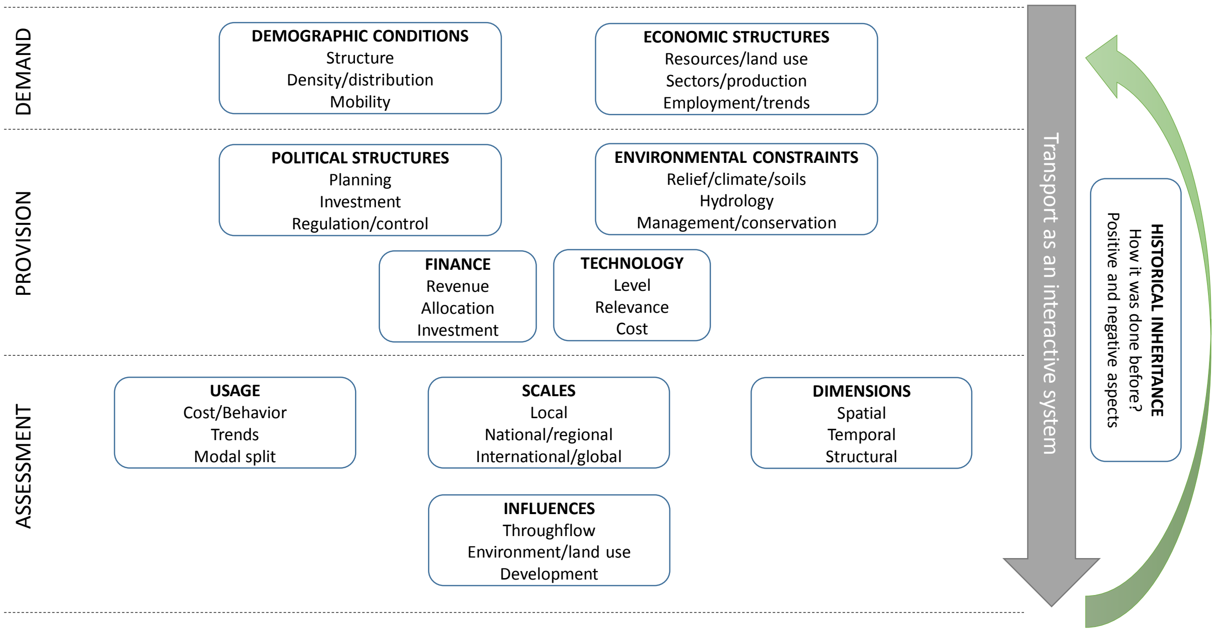


Figure 14: Factor-based framework of modern transport geography (Source: adapted from Hoyle and Knowles (1998))

This section draws reasons that encourage the implementation of a transportation system. Furthermore, it presents the factors that are related to transportation as an interactive system and introduces the socio-spatial factor, which normally, is conditioned to this system. For a more specific analysis of the relationship between transportation and urban structure, there must be an understanding of the effects of transportation on the spatial structure, which is reviewed in the subsequent sub-section.

3.1.1. The Transportation System and Urban Spatial Structure

The spatial organisation can be determined on two dimensions (Rodrigue, Comtois, & Slack, 2013, pp. 42-87). The first is related to spatial differentiations based on location, size and density, illustrating the distribution of features, such as the different types of land use. The second is related to spatial interactions, regarding origin, destination and flows, which implies transportation and mobility factors.

According to Rodrigue et al. (2013, pp. 42-87), “space shapes transport as much as transport shapes space”, which can be represented by the relationship between the reciprocity of transport and geography. This reciprocity is articulated over two perspectives, the reciprocity in location and in mobility.

The reciprocity in location concerns the components of the transport system, links and nodes, in the spatial structure. This system of nodes and links shapes the organisation of space, in terms of locations and relations. Figure 15 illustrates the transport reciprocity in location, by presenting a hypothetical city that has a metro network. It is possible to observe that the transportation network shapes the spatial distribution of the urban structure, analysing the design of the transportation system and disposition of land use. The transport system of Figure 15 could be composed by one mode or a mix of different modes, influencing the capacity of the system.

As transport geography emerged from economic geography, it is acknowledged that the transportation factor is strongly related to the economic representation in space, such as the monetary cost of distance between elements of the urban space (Rodrigue, Comtois, & Slack, 2013, pp. 1-41). Thus, the transportation system can be considered as one of the factors that influences the linkage between elements of the city, such as residential to labour demanding areas (e.g. Central Business District or commercial area) or consumers to retail shops. This logic is linked to the second type of reciprocity, in mobility.

The transport reciprocity in mobility is related to the activities that are dependent on transportation. Based on the influence of transportation on economic activities, a land use can have good accessibility by being close to the nodes of the system, which are origin and destination points (terminals). Figure 15 shows the dependency of the mobility on the transport system, which improves accessibility from origin to destination, towards attending the demand (volume and frequency of trips).

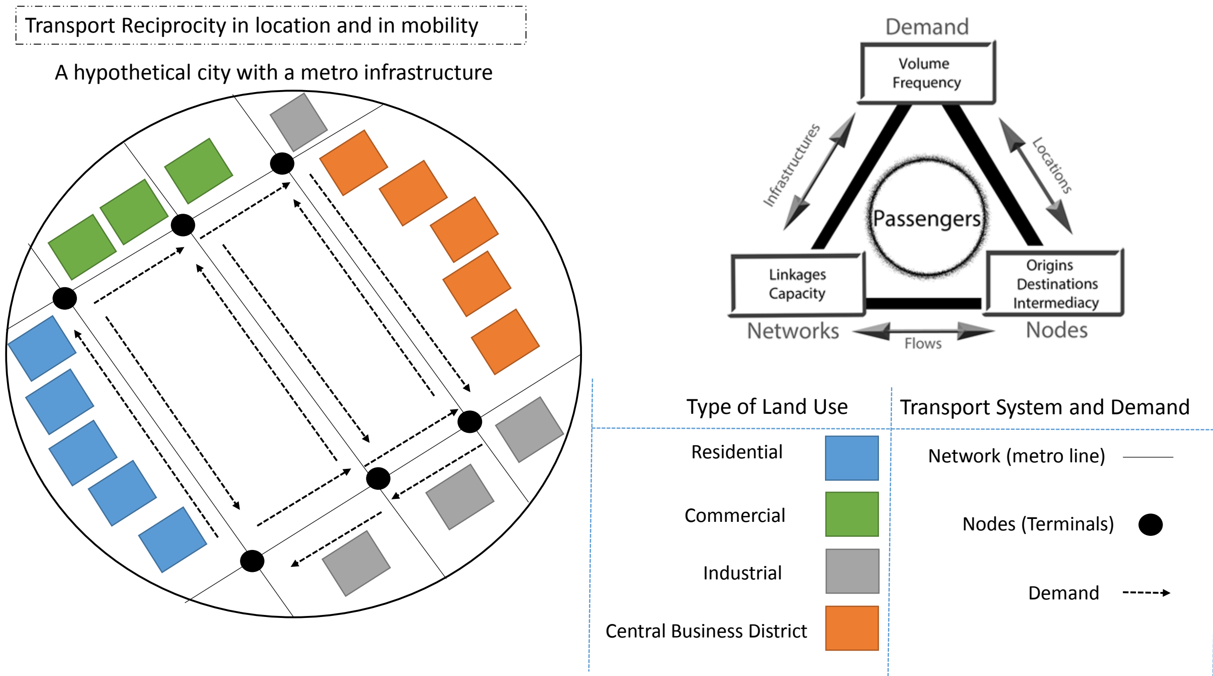


Figure 15: Transport reciprocity in location (Source: adapted from Rodrigue et al. (2013, pp. 1-87))

As the urban space and transportation system can have a reciprocal relationship, it is important to understand the characteristics of a transportation system regarding its topology and typology, which are represented in the urban space. According to Rodrigue et al. (2013, p. 24), as transportation network have a geographical setting, they can be represented relative to location (Figure 16) or even abstractly represented, which doesn't mean illustrating the network exactly where it is. The network is represented by orientation and extent, which includes a set of locations (nodes) and links connecting places.

Figure 16 shows an illustrative representation of a transportation network in an urban area. It is observed that routes (e.g. roads, rail links and maritime routes) and terminals (e.g. port, train station and bus stop) can compose a transportation network. Furthermore, each link between nodes can have specific information, such as volume, capacity, direction, price, distance, road type and control information. Figure 16 also shows that the links can be related to the location, regarding physical characteristics, such as cost lines and other geomorphological shapes (hills, valleys and rivers).

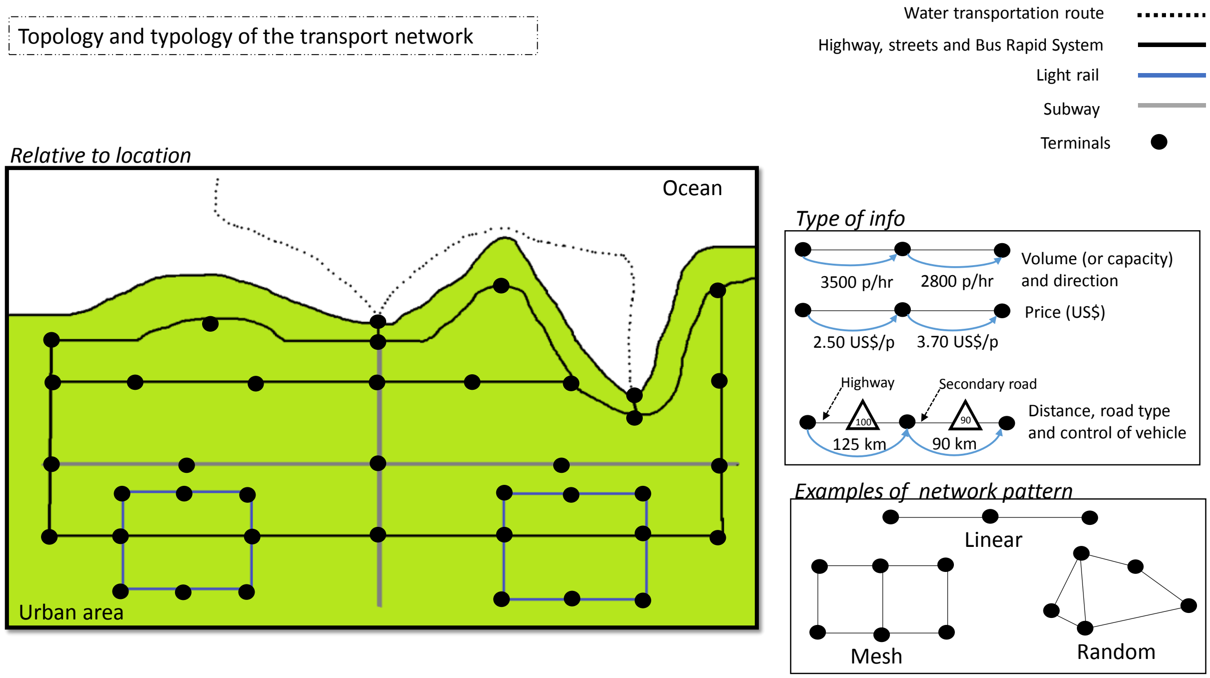


Figure 16: Illustrative transportation network (Source: based on Rodrigue et al. (2013, pp. 1-87))

To have a more objective view over the relationship between transport system and urban environment, Wegener (2004) developed a land-use transport feedback cycle (Figure 17). Figure 17 is described through four patterns of land-use and transportation relationship (Wegener, 2004).

The first pattern is that the land use distribution over the urban area determines the locations of human activities, such as residential, commercial or industrial. The second is that this distribution of activities creates the need for spatial interaction or trips within the transport system in order to overcome geographical constraints between locations of activities. The third pattern is that the transport system creates conditions and opportunities for spatial interactions, which can be measured by the accessibility. The last pattern is related to the distribution of accessibility in space, which can influence location decisions and consequently, changing land use. (Wegener, 2004)

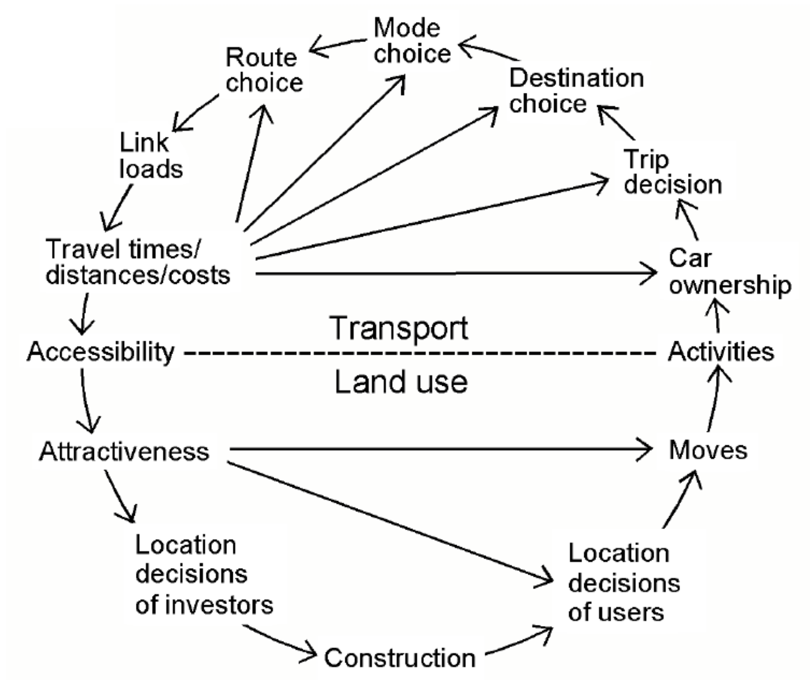


Figure 17: The land-use transport feedback cycle (Wegener, 2004)

According to Wegener (2004), Figure 17 is an overall way to approach the relationship between transportation and urban structure, frequently used by engineers and geographers. Towards a more specific analysis, Wegener (2004) identified over 20 contemporary models of urban land-use transport. From his overall analysis, it was noted that there is still much to be developed, regarding these models. This is because there are still issues that are not taken under consideration, such as environmental impact (that are not only related to air pollution), social exclusion and spatial equity (Wegener, 2004).

From the economical-geographical perspective pointed out by Coe et al. (2007, p. 123), it is necessary to understand the technological changes and their geographical impacts. To proceed with this understanding, it is necessary to know the difference amongst technology, technological change and its spatial ramifications (Coe, Kelly, & Yeung, 2007, p. 123).

According to Coe et al. (2007), technology emerges through a social process, "which individuals and organizations deploy technologies to achieve certain ends" (p. 123). Furthermore, it is important to understand how technologies facilitate and enable changes using different economic factors (Coe, Kelly, & Yeung, 2007).

Coe et al. (2007) affirm that there are two types of space-shrinking technologies, which generate geographical impacts, overcoming friction of space and time: transport systems and communications technology. The transport system is seen as “the means by which material goods (including people) are transferred between places” (Coe, Kelly, & Yeung, 2007, p. 125). The communication systems “enable the transmission of various kinds of information between places” (Coe, Kelly, & Yeung, 2007, p. 125), such as text, numbers, images, videos, music and computer programs.

Within the competitive capitalist economy, the firms are constantly improving different parts of the production process, based on three aspects (Coe, Kelly, & Yeung, 2007, p. 125): technique, scale and location. The technique is related to the combination of labour and capital (Coe, Kelly, & Yeung, 2007). The scale is related to the economies of scale, taking advantages of cheaper means of production and reaching bigger markets (Coe, Kelly, & Yeung, 2007). The location has to do with what the company needs, in terms of labour (cheap or highly skilled), source of inputs (e.g. ray material, components or management consultants) or market (e.g. final consumer, other companies or government departments) (Coe, Kelly, & Yeung, 2007).

In order of the possible priority combination, which a firm can have, Coe et al. (2007, p. 133) present three different types of industrial systems that co-exist in the contemporary economy, presented in Table 2: flexible specialisation, Fordist mass production and Japanese flexible production.

Table 2: Alternative production systems in post-Fordism (Coe, Kelly, & Yeung, 2007, p. 133)

Characteristic	Flexible specialization	Fordist mass production	Japanese flexible production
Technology	Simple, flexible tools/machinery; non-standardized components	Complex, rigid single-purpose machinery; standardized components; difficult to switch products	Highly flexible (modular) methods of production; relatively easy to switch products
Labour force	Mostly highly skilled workers	Narrowly skilled professionals 'conceptualize' the product; semi/unskilled workers 'execute' production in simple, repetitive, highly controlled sequences	Multi-skilled, flexible workers, with some responsibilities, operate in teams and switch between tasks
Supplier relationships	Very close contact between customer and supplier; suppliers in physical proximity	Arms-length supplier relationships; stocks held at assembly plant as buffer against disruption of supply	Very close supplier relationships in a tiered system; 'just-in-time' delivery of stocks requires 'close' supplier network
Production volume and variety	Low volume and wide (customized) variety	Very high volume of standardized products with minor 'tweaks'	Very high volume; total partially attained through the production of range of differentiated products

Reviewing the geographical configurations of these three production systems, naturally leads to the topic of agglomeration economies (Coe, Kelly, & Yeung, 2007, p. 136). There a two types of agglomeration economies: urbanisation economies and localisation economies. According to Coe et al. (2007), these two types of agglomeration economies are defined as:

1. **Urbanization economies**: "The general clustering together of activities in towns and cities creates the potential of sharing the costs of a wide range of infrastructure (e.g. airports, road and rail networks) and services (e.g. universities, hospitals and libraries) among diverse firms, and for accessing large urban markets" *(p. 137)*

2. **Localization economies**: "These refer to the cost saving that accrue to firms within the same or related industry through locating in the same place. These may derive, for example, from the presence of specialized pools of skilled

> labor, from access to industry-specific services and institutions, or form the development of a local knowledge base" *(p. 137).*

It is the second agglomeration economy type that have gained the attention of economic geographers in recent years, "as it is central to after-Fordist agglomeration dynamics" (Coe, Kelly, & Yeung, 2007, p. 137).The possibilities of the production processes regarding fragmentation and separation stages generate impacts over space (Coe, Kelly, & Yeung, 2007). However, according to Coe et al. (2007), these changes in the production processes, in many cases, led to uneven social and geographical aspects.

This section regards the visualisation of the transportation system in the urban structure, understanding that the transportation network can have different designs and characteristics (e.g. such as mode, technical specifications, price, capacity, etc.) according to geomorphological, economic, land use and demanding aspects. It was also seen that there is interactive transportation system that is composed of different factors, which can be having a reciprocal relationship with the urban structure.

3.1.2. A Close look to Transportation and Urban Development

This section examines the role of transport in the process of spatial change, focussing on the urban environment. To have a better understanding of the relationship between transportation and urban development, at first, two core concepts must be acknowledged, which are accessibility and mobility. According to Hanson (2004), accessibility refers to the number of opportunities (activity sites), available within a certain distance or travel time; and mobility is the ability to move between different activity sites (e.g. from home to grocery store).

A city possesses different land uses within its space, such as residential, commercial or industrial areas. On one hand, depending on the level of accessibility, improving transportation can be necessary. On the other hand, improvement in transportation can encourage the development of new land uses (Hanson, 2004). This means that a good accessibility does not necessarily mean that there is a good mobility. If there is, e.g. a determined neighbourhood, where all residents have a school within an average walking time of 30 minutes, it can be affirmed that there is good school accessibility. However, if the residents of this same neighbourhood need to go to the other neighbourhood to access school by bus, then the mobility and accessibility starts getting affected, mainly because constraints start to appear, such as bus frequency and price. In this case, people who have low income and cannot afford a car will depend on the bus frequency, and those who can afford a car will have better mobility, because they will have the ability to move between home and school at any time.

However, cities have a complex structure with many kinds of activities and trip patterns. To understand the relationship between land use and mobility better, this section reviews cases of metropolis growth in developing and developed countries, based on the literature review, focussing on the case of the United States of America (USA) and the other case being Brazil, in particular, the city of Rio de Janeiro.

3.1.2.1. United States of America

Regarding the case of the growth of US cities and transport development, Adams (1970) developed a study that identifies four eras of intraurban transport patterns that had a direct relationship with the built-up urban areas in the US (Figure 18). As shown in Figure 18, the four transport eras are as follows: (1) Walking-horsecar Era (1800 – 1850); (2) Electric Streetcar Era (1890 – 1920); (3) Recreational Automobile Era (1920 – 1945); and (4) Freeway Era (1945 – present).

According to Adams (1970), some periods provided a transport spatial occupation, while others depended on a sharply defined network of movement in certain routes. The author means that the first and third eras of mobility was provided in a surface, while in the second and fourth eras of mobility was limited to sharply delineated channels and nodes (Figure 18)

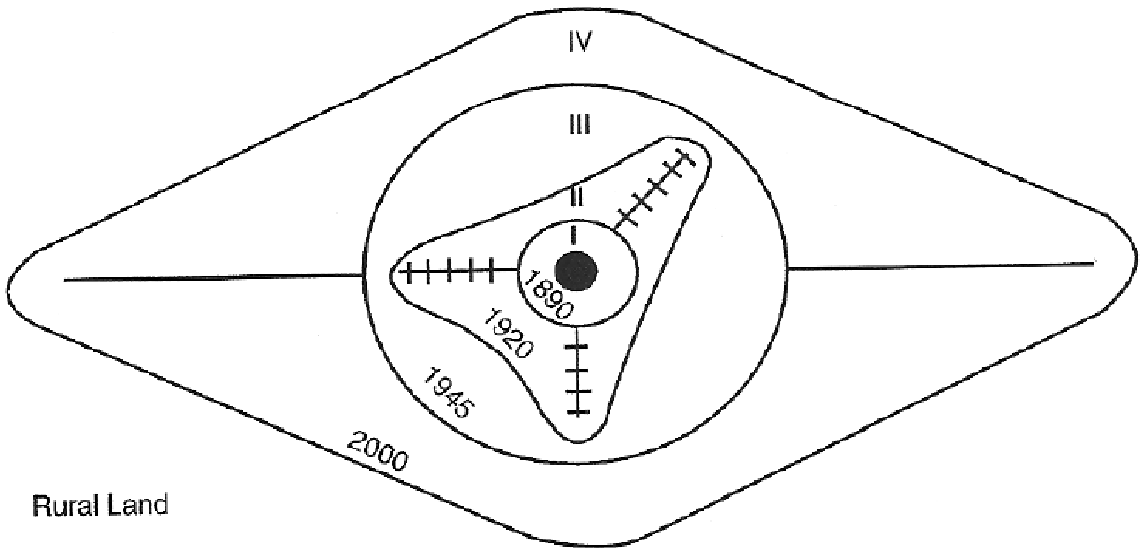


Figure 18: Intraurban transport eras and metropolitan growth patterns (Muller, 2004)

Based on Adams' (1970) transport eras, Muller (2004) analyses some cases in the US. Muller (2004) affirms that before the 19th century, cities in the U.S. were highly agglomerated, thus clusters were created in order to provide spatial proximity between people and activities. At that time, this meant an average of 30 to 45 minutes of walk or less. However, those who could afford a horse-drawn carriage would usually reside in the nearby countryside, escaping from the cities' noise and frequent epidemics, which resulted from unsanitary conditions. With the introduction of railroads in 1830s, businesspersons who worked at the centre of cities, such as Boston, New York and Philadelphia, started to live further away from their working places. Thus, commuting became their daily life activity but, those who could not afford horse-drawn carriages or train tickets, resided in the city centre, in small, overcrowded quarters (Muller, 2004).

Industrialisation in the mid-19th century generated a physical and social worsening of the city centre and besides, it also led to middle-income residents to suburbanise. Therefore, walking to work was not a 30- or 45-minute walk anymore. Muller (2004) believes this as one of the factors that brought the need to improve intraurban transport. In 1852, horse-drawn streetcars were introduced in New York City. This new solution at the time brought an increased mobility reach, because radial routes were implemented, thus opening new home constructing areas, which proliferated in the 1980s, creating the horsecar suburbs (Muller, 2004). However, even with the horse-drawn streetcars, mobility issues were not solved, because Europeans kept immigrating to cities of the U.S. to work in the industries. Moreover, as salaries were low, they could not afford transportation costs, thereby forcing them to live near the factories, which is why cities continued to be agglomerated and overcrowded. Therefore, cities still needed an even more effective transportation solution.

At the end of the 19th century, the electric traction motor was invented and implemented in Richmond, Virginia in 1888 (Muller, 2004). By the 1890s, the electric streetcar had a significant role in intraurban mobility in U.S. cities. According to Muller (2004), electric streetcars shaped a newly built environment. Horse-drawn streetcars were built in a radial pattern, and along the streetcar lines, there were commercial facilities that gridded residential streets and reached out several blocks on both sides of its rail line (Muller, 2004). In Figure 19, Muller (2004) shows the example of Massachusetts, presenting how streets were gridded with the streetcar line, shaping new residential areas.

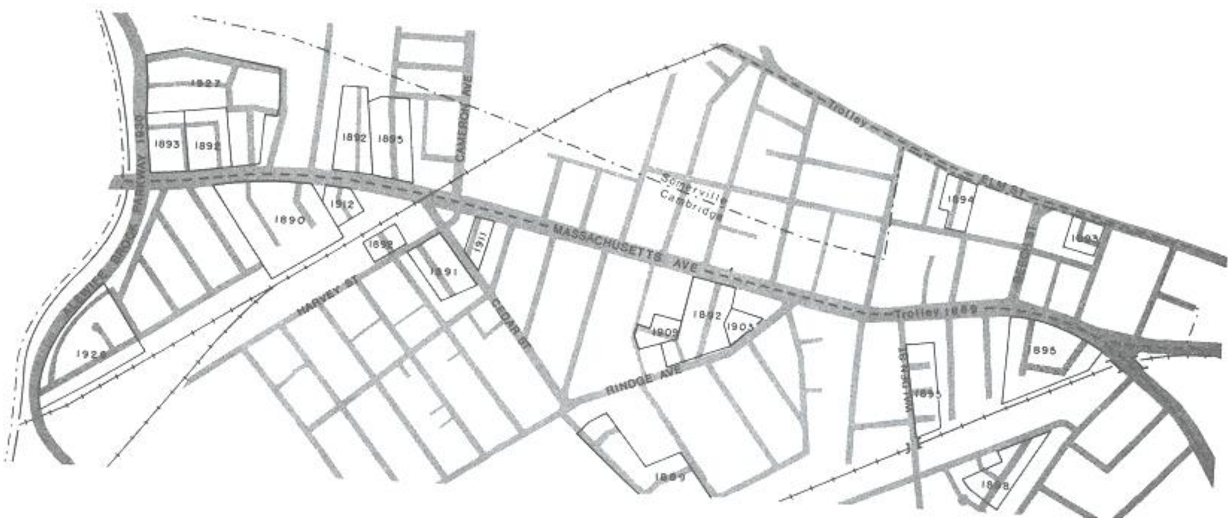


Figure 19: Streetcar subdivision outside Boston in North Cambridge, Massachusetts, 1890 – 1930 (Muller, 2004)

After the first electric streetcars, additional improvement in urban rail transportation was made. By 1868, New York implemented an electric elevated rail and by 1898, Boston implemented subways. As this technology had always been expensive, the construction was justified only in the largest cities, such as New York, Boston, Philadelphia and Chicago (Muller, 2004). Furthermore, most of these constructions ended by the 1920s, but later on, rail transportation was implemented in other cities of the U.S.

By 1920s, there was already a mass production of cars at accessible prices for a higher range of social classes. However, initially cars were used for weekend outings, establishing the Recreational Auto Era (Muller, 2004). Introduction of cars in the U.S. cities generated, for the first time, a higher growth of the suburbs in comparison to the central cities, as residents of the suburbs started becoming more dependent on private transport, because the cities expanded beyond the reach of rail transportation (Muller, 2004). The growth of the automobile use generated a crisis on the urban transit sector, which could not attract investments to improve the public transportation. In the 1929 crisis, urban transit deteriorated further, because it lost investments. However, the growth of car use decentralised residential and non-residential activities. After World War II, the freeway era began (1945 – present).

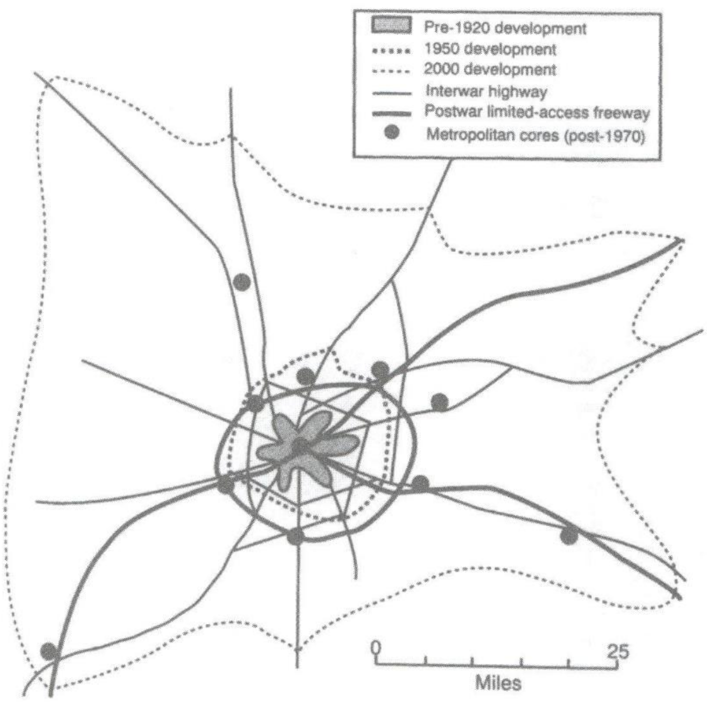


Figure 20: The spatial pattern of growth in the automobile suburbia since 1920 in the U.S. (Muller, 2004)

Figure 20 shows the urban growth during the freeway era. From this figure, it is difficult to neglect the growth after the construction of freeways and consequently, the encouragement for a massive use of private transportation. According to Muller (2004), the growth of long distance interstate highways stimulated the decentralisation of residential, commercial and industrial activities, thus generating a more polycentric logic, which can be identified with the appearance of suburban downtowns. The suburban downtowns turned into significant business centres, with high employment rates in comparison to the city centre. For example, Philadelphia's metropolitan area in 1998 had a suburban percentage of 72% in the major employment sector, while 28% of the jobs were in the city centre.

The present U.S. urban growth systematics is observed in the largest cities of the U.S., such as New York, Los Angeles and Chicago. Even though transportation issues are not the only forces shaping intraurban growth and spatial organisation, it is still a significant factor, which leads to spatial changes and human behaviour towards mobility. As urban growth is closely related to transportation patterns in the U.S., it is possible to affirm that these big cities in the U.S. grow with a mobility highly dependent on private transportation. For example, in 2008, Chicago transport mode share (Figure 21) presented that 63% of trips were made by private transport and 37% by other modes.

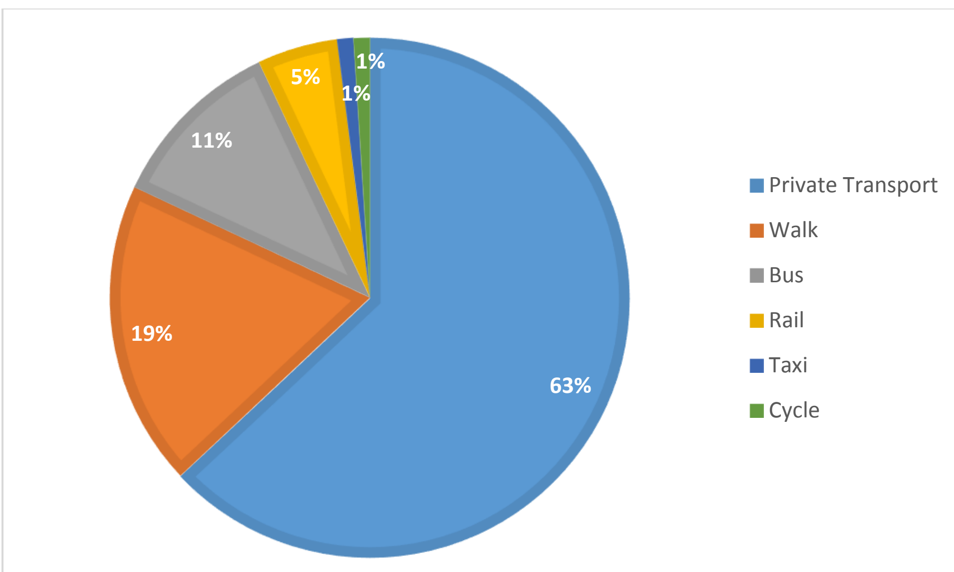


Figure 21: Chicago Transport Mode Share in 2008 (%) (LTA, 2011)

In the case of US cities, it is seen that the development of the transportation sector decentralised land use, such as industrial, residential and commercial. Furthermore, the transport development built a scenario, which allowed the growth of suburban areas that further on, some of them, turned into new centres, with services and commercial areas being comparable to the core of cities (Gallagher, 2013).

3.1.2.2. Brazil: Case of Rio de Janeiro

In Brazil, as there is not much work in the field of the urban structuring process from a temporal perspective (Abreu, 2008), it is more difficult to develop a correlation between urban growth and transportation development. Therefore, this section presents a mix review of the work entitled "The Urban Evolution of Rio de Janeiro" from Abreu (2008) and other references, with the intention to understand the urban growth process and the role of the transportation sector on this process.

As Abreu (2008) affirms, it is not possible to apply urban growth models based on developed countries in Brazil, because the socioeconomic conditions are different, as is the industrial and urban infrastructure development process. For a more particular analysis of Rio de Janeiro's metropolitan area, the author begins by understanding the social-spatial formation historically, because it represents the urban space production (flow, distribution and consumption).

In the beginning of the 19th century, the city of Rio de Janeiro was limited and concentrated (Figure 22). The city accommodated different social classes together, due to the lack of transportation infrastructure. This scenario started to change in the 1870s with the implementation of trams powered by donkeys and steam-power trains.

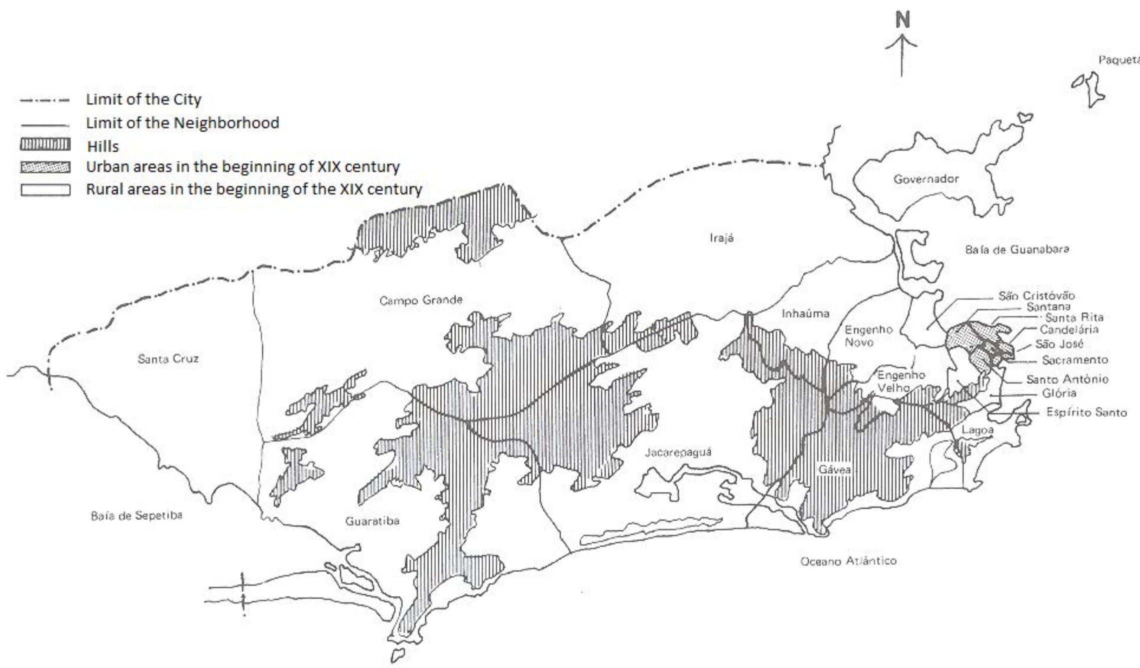


Figure 22: City of Rio de Janeiro: Neighbourhoods of Rio de Janeiro in the XIX century (Abreu, 2008)

Figure 23 shows the implementation of railroads at the end of the 19th century in the metropolitan region of Rio de Janeiro. These railroads generated a suburbanisation process and changed the appearance of the metropolitan region. However, even with the implementation of railroads, the tram system in the core of the city still transported more people than the train system. The low-income families occupied the suburban areas. The high-income families continued to live in the core of the city, because main services and industries were not decentralised at the time.

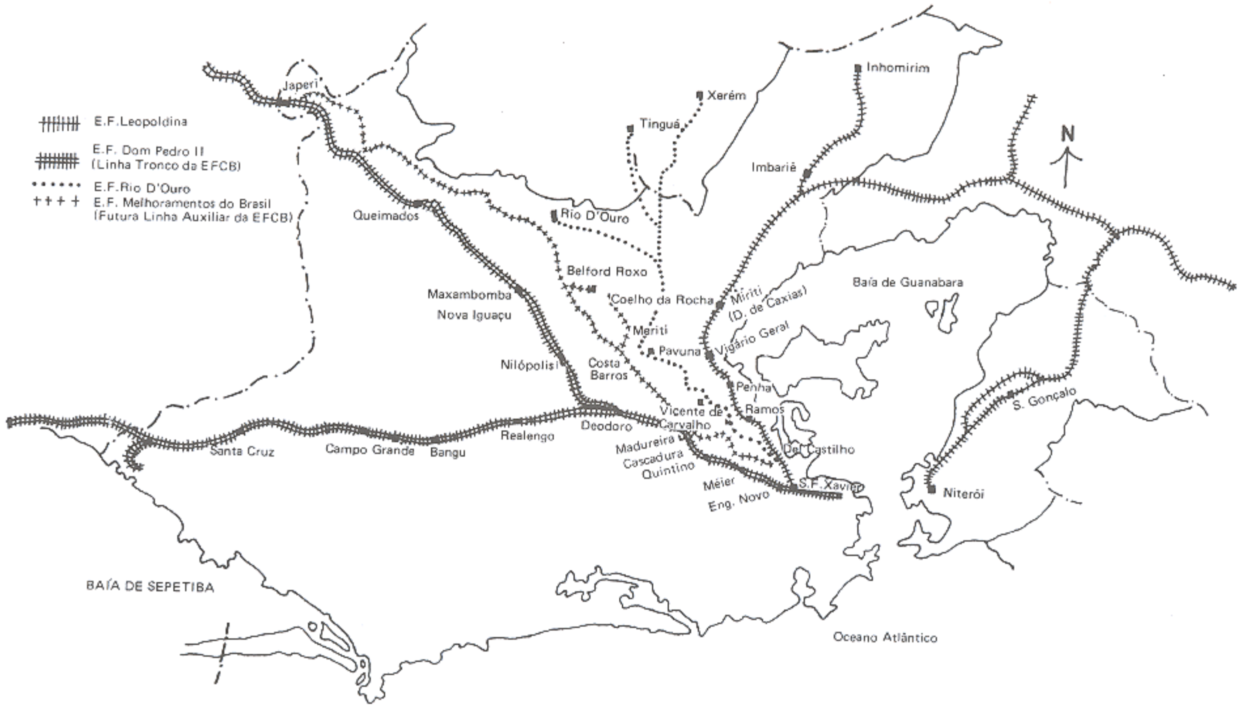


Figure 23: Metropolitan Region of Rio de Janeiro: Railroads Localisation (end of the XIX Century) (Abreu, 2008)

Reforma Passos characterised the beginning of the 20th century as a process of urban restructuring of the city of Rio de Janeiro. This restructuring was based on enlargement of streets and creation of new avenues for circulations. However, these processes were limited to the core of the city and parts of the south zone. From 1906 to 1930, the changes in the city strengthened social-spatial differences, because families with low income moved to the north zone of the city (suburb) and those with high income stayed in the south zone and the core part of the city. The creation of local infrastructure in the suburbs was, initially, due to the movement of industries to these areas, while the State invested in the restructuring of the core and south zone of the city. It is possible to see in Figure 24 that after the1930s, the displacement of industries in Rio de Janeiro to the suburbs was closely linked with the railways. This fact complements the State project to create industrial zones close to railways and highways.

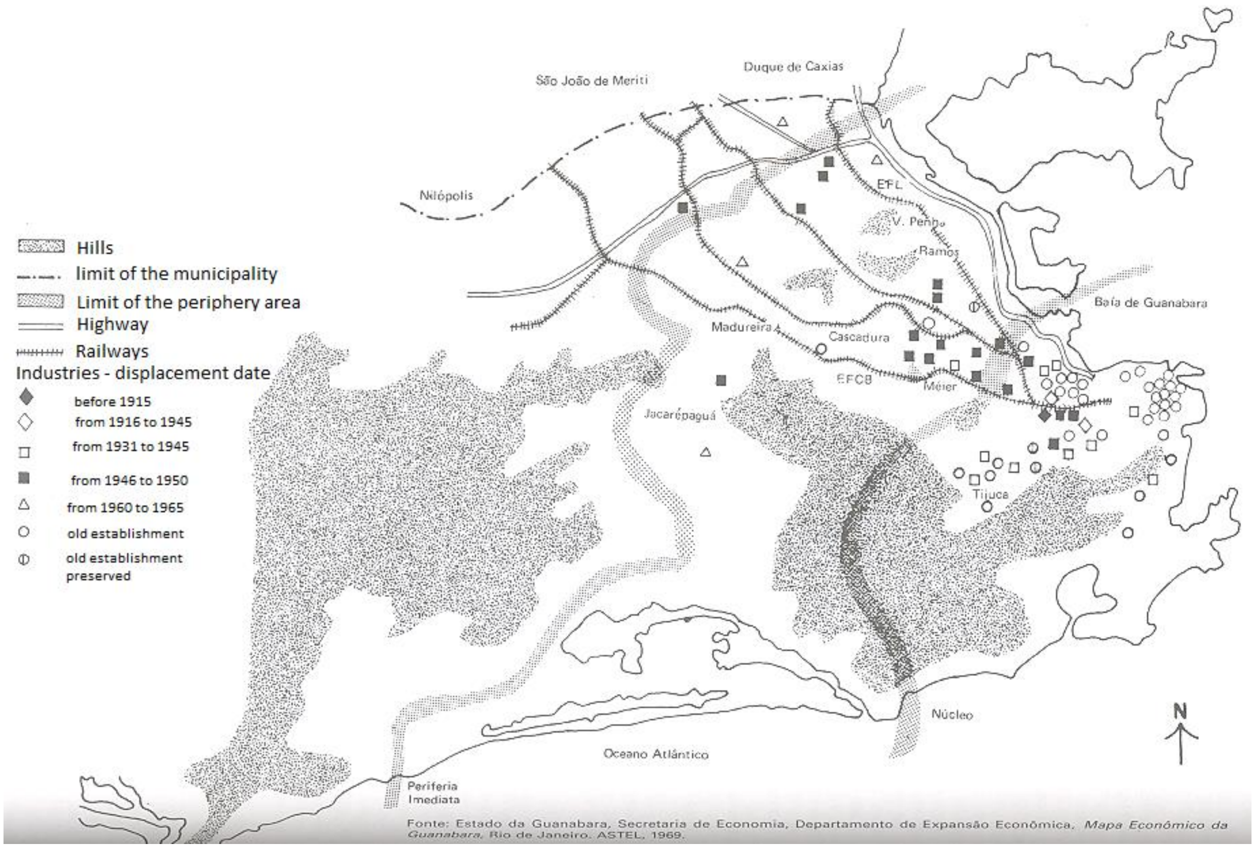


Figure 24: City of Rio de Janeiro: Displacement of middle and large industries until 1965 (Abreu, 2008)

The whole process of renewing the city and building infrastructure generated an increase in land value, which mainly stimulated the growth of *favelas* (in English: Slums) and the movement of families with low income far from their work places.

The 1960s are highlighted by the State’s investments in building bridges, avenues and tunnels to connect the city, stimulating the use of private cars. This growth of the automobile infrastructure in the city coincided with the growth of the automobile industry in Brazil (Caputo & Melo, 2009).

In 1979, the metro system of Rio de Janeiro began to work (Metro Rio, 2015), and today it is composed of 40.9 kms of railway, which has 35 stations (SINERGIA, 2014). The metro of Rio de Janeiro attends to a limited part of the city. According to a 2012 data (Prefeitura do Rio de Janeiro, 2014), it carries 669 thousand people daily, while the bus system carries, approximately, 3 million, the train 528 thousand and water transportation 106 thousand. According to the same source, the city has 2,622 million cars, which probably are used daily. Availing buses as public transport is dominant in the city of Rio de Janeiro, as is also in other developing countries (Vasconcellos E. A., 2014a).

What happens in Rio de Janeiro was observed by Vasconcellos (2014a) as a general occurrence in developing countries. There are usually better conditions for those with access to private transport, above all in peripheral areas, because there are worse conditions of public transport and less accessibility to it.

Figure 25 shows the neighbourhood's population of the city of Rio de Janeiro. From this figure, it is possible to observe that the peripheral areas are the most populated, and the areas around the core of the city, which is represented by the number 5 are less populated. However, it is around the core of city that there is better accessibility to public transportation. The urban expansion of this city is based on private automobile accessibility, mostly, the west part (which is 60% of area of the city) (de Souza Vieira, 2011), because since the 1980s until recently, low attention has been given to public transportation. Furthermore, approximately 30% of all job positions are placed in the centre of the city and its surroundings, composed by number 5 and 7 (Figure 25), and 12% of them are placed in the neighbourhoods composed by number 128 and 115 (Prefeitura do Rio de Janeiro, 2014). Therefore, approximately, 40% of the job positions are placed in 4 from 160 neighbourhoods of Rio de Janeiro, generating a high rate of daily commuting in the city.

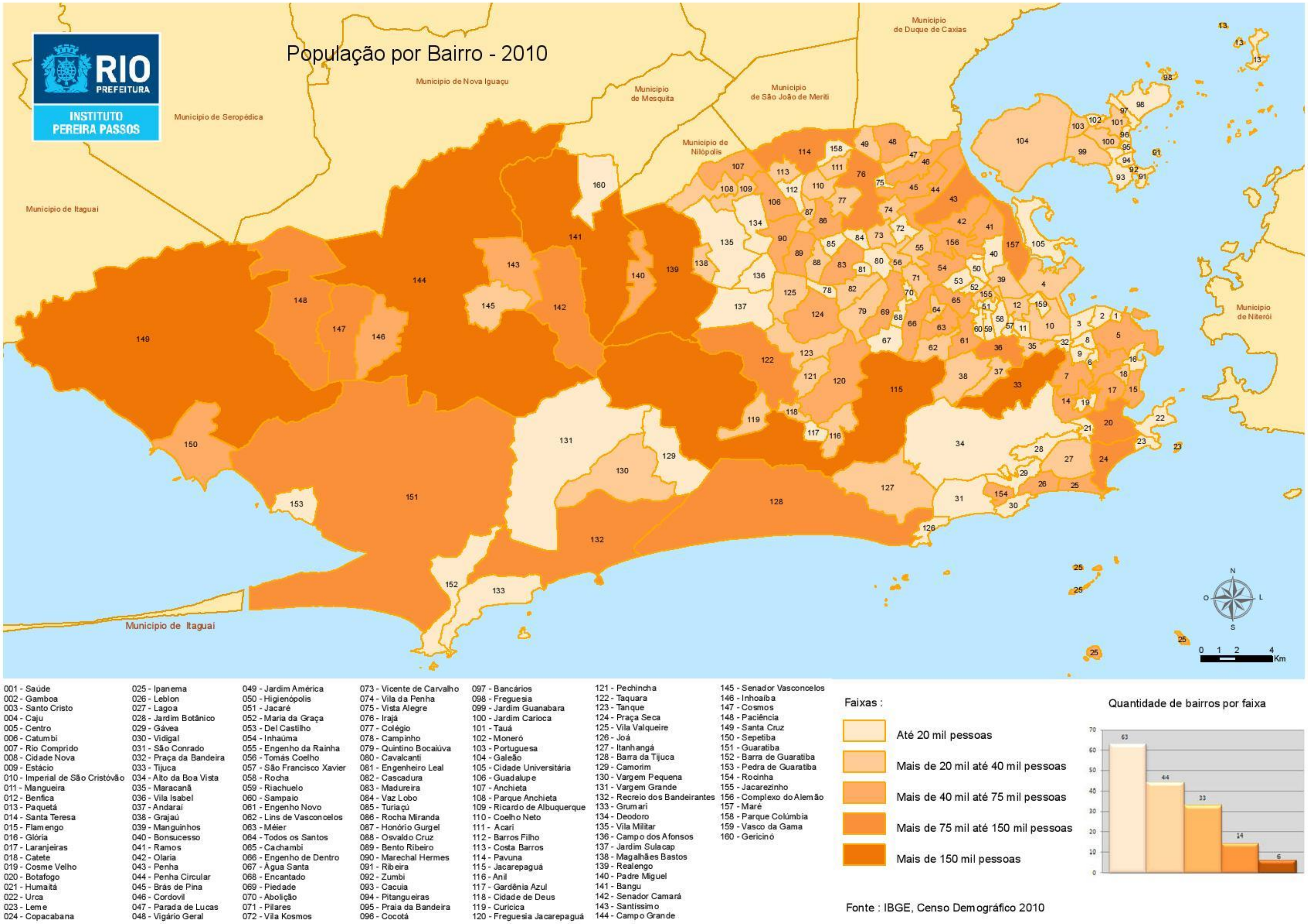


Figure 25: Population by Neighbourhoods in the City of Rio de Janeiro (Prefeitura do Rio de Janeiro, 2010)

In the case of Rio de Janeiro, it is possible to see that the urban growth has a close relationship with transportation development. In the beginning of the 19th century, the city was limited to the centre and its surroundings, because of limited transportation options. With the implementation of railways, towards the end of the 19th and in the early 20th century, suburbanisation increased and industries were decentralised in the direction of the north part of the city. At the end of the 20th century, the growth of the auto industries stimulated the growth of the infrastructure for trucks and cars, thus encouraging the urban growth in direction of the west part of the city, firstly for residential use and then also for commercial use.

3.2. Transportation Planning Process

According to Wachs (2004), transportation policy provides society with the benefits of transportation services, while reducing their costs as much as possible. To reach a balance of costs and benefits, there are requirements to be considered, such as effectiveness, efficiency and equity (Wachs, 2004).

Effectiveness regards the level to which the transportation system meets its intended objective (Wachs, 2004). Efficiency is related directly to cost-benefit, evaluating whether there are benefits provided in relation to the applied investment (Wachs, 2004). Equity consists in bringing fairness to society, considering monetary and environmental factors and effectiveness level (Wachs, 2004).

Through a historical analysis, Jones (2014) reviews the evolution of urban transport policies, and relates them to the conceptualisation changes of what urban mobility involves. The author characterises the evolution of urban transport policies over the past 50 years, broadly speaking, in a three-stage process.

The first stage involves traffic growth policies, from a vehicle-based perspective (Jones, 2014), which means that in the late 1960s, there was a rapid increase in car ownership and use, and the majority of solutions to improve the cities' mobility were based on road building and maximising vehicle capacity on existing urban streets. At this stage, there is also a cut back in the investments on public transportation sector and road spaces are taken away from street activities (e.g. market stalls), pedestrians and cyclists (Jones, 2014).

The second stage includes traffic containment policies, from a personal trip perspective (Jones, 2014), meaning that cities started to give more importance to the origin to destination movements. Based on the argument that rail transportation could almost be as fast as cars and could carry more people, there was an expansion of railway systems in the big cities of Europe. While in South America, the focus has been on building Bus Rapid Transit (BRT), due to implementation price, which is lower than rail transportation (Jones, 2014).

The third stage is about liveable cities, from the activities and quality of life perspectives (Jones, 2014). At this stage of evolution of urban mobility policies, there is an increasing concern with the cities' activities and quality of life. This third stage includes questioning the necessity of physical movements, whether some activities can be done without a trip, e.g. internet shopping, home office or flexi-time at work, to encourage peak-hour spreading (Jones, 2014). The latest urban mobility policies also encourage walking and cycling in the urban environment. Therefore, this mobility policy stage intends to reduce the use of car, and shifts to sustainable transport modes, also promoting street activities and improving the urban quality of life (Jones, 2014).

According to Johnston (2004) and Rodrigue et al. (2013), it is possible to establish roughly two types of transport planning process, which have been used during the last 50 years: the traditional transportation planning and the contemporary transport planning.

Transport planning is a process responsible for the preparation and implementation of actions that addresses a specific problem or focusses on a broad transport concern at a local level. (Rodrigue, Comtois, & Slack, 2013, p. 280). According to Vasconcellos (2014a), transportation planning differs from urban planning, because the main concerns of urban planning regard land use and the physical provision of public services, such as water, sewage collection, schools and medical services). Transportation planning aims at the circulation's infrastructure (pavement, roads, railways and terminals), transportation modes and traffic management.

According to Rodrigue et al. (2013, p. 285), "transport planning is most developed in the urban sphere". Generally, the transport planning process can be compared to the policy process, which involves, basically, the identification of the problem, seeking options and implementing the chosen strategy (Rodrigue, Comtois, & Slack, 2013). Furthermore, usually, planning public transport is government task, which can be done in a lightly regulated, unregulated or highly regulated market (Vasconcellos E. A., 2014a).

According to Johnston (2004), transport planning did not include travel modelling before World War II. With the increase of automobile ownership in cities (in developed and developing countries) and the widespread suburbanisation, there was an increased investment in the transportation sector (Johnston, 2004). Therefore, in the1940s, transport planning aimed at the modelling of travel behaviour, which can be considered as the traditional transport planning process (Rodrigue, Comtois, & Slack, 2013, pp. 280-303; Johnston, 2004).

The traditional transport planning within cities was dominant between 1940s and 1980s (Rodrigue, Comtois, & Slack, 2013). This planning process consisted four major steps of evaluation (Johnston, 2004; Rodrigue, Comtois, & Slack, 2013): trip generation (how many trips?); trip distribution (where do they go?); modal split (by what modal choice[s]?) and traffic assignment (by what route?). In addition, it is observed that this process was dominant during the first two stages of transport policies.

Traditional transport planning has some gaps, which can also be considered as caution points (Rodrigue, Comtois, & Slack, 2013; Johnston, 2004). The main observations (caution points) are as follows:

- Most of the time the data are inaccurate or incomplete, meaning that the results may not be representing reality;
- The data can be manipulated towards the intended results, which clients would prefer;
- Most of the studies are based on mathematical assumptions and the validity of results are, usually, not questioned;
- Non-motorised modes are omitted.

The traditional planning was a significant factor responsible for the expansion of highways, consequently reinforcing the dominance of automobiles in urban spaces (Rodrigue, Comtois, & Slack, 2013). Even if this type of planning identifies results close to reality, they usually represent a limited time and space scale, therefore, leading to mitigating solutions within these limits.

One can say that the problem is continuous, as car ownerships are increasing in many developing and developed countries. This means that even if expansion of highways and streets can mitigate a capacity problem, it will be for a certain time. Because urbanisation viewed from a global perspective is a contemporary and ongoing process for most countries (Pacione, 2005). The proportions of population living in urban area are increasingly growing, as the urban life requirements may also be growing, such as car ownerships.

Figure 26 shows the historical view of passenger cars' growth in the European Union and Latin America, from 2003 to 2009. The data shows that passenger cars have been growing during this period in Europe and Latin America.

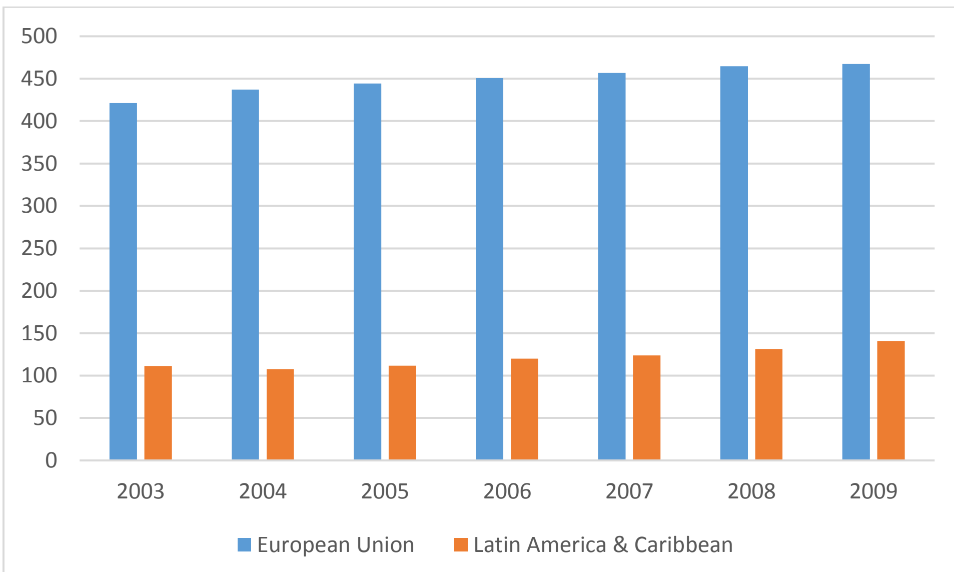


Figure 26: Passenger cars (per 1,000 people) – European Union and Latin America (World Bank, 2015)

The company TomTom has made a list of ten cities in the world with the worst traffic conditions, based on the percentage of time spent in traffic during peak hours, whose base line is the rate of freely flowing traffic in the respective cities (Gorzelany, 2014):

1. Moscow, Russia: 74%
2. Istanbul, Turkey: 62%

3. Rio de Janeiro, Brazil: 55%
4. Mexico City, Mexico: 54%
5. São Paulo, Brazil: 46%
6. Palermo, Italy: 39%
7. Warsaw, Poland: 39%
8. Rome, Italy: 37%
9. Los Angeles, USA: 36%
10. Dublin, Ireland: 35%

The point is that even in recent years, traffic problems are still apparent in developing and developed countries. Transportation planning solutions that are limited to the traditional view are not enough for a long-term perspective. According to Rodrigue et al. (2013), the cities' traffic problems increased significantly since 1970s, although the urban transport planning became a more frequent process. It has been noticed that new constituents of transport planning are being developed to improve mobility conditions, which are within the contemporary transport planning approaches.

Contemporary transport planning is still considered as a multi-step process, which has some changes when compared to the traditional transport planning (Rodrigue, Comtois, & Slack, 2013). From an overall view, contemporary transport planning is strongly linked to managing demand, whether or not building a capacity planning (Rodrigue, Comtois, & Slack, 2013).

Rodrigue et al. (2013, pp. 280-303) pointed out five elements, which show changes in the planning process and lead to the increase in the complexity of this process: (1) goals and objectives; (2) options; (3) identification of actors, institutions and stakeholders; (4) predicting outcomes, identifying benefits and assessing costs; and (5) choosing course of action.

The first element, regarding goals and objectives, is the one that expands the complexity of transport planning. This means that depending on the objectives and goals there can be a set of options (second element) and scenarios to be considered, and those would be the important elements in the process.

Because concerns of the transportation sector have expanded to a multidisciplinary scope, the objectives consider environmental, social and economic aspects, such as improving safety and health; reducing emission from vehicles, improving equity, enhancing economic opportunities; improving community liveability and promoting mobility.

The third one is related to actors, institutions and stakeholders. Besides understanding the institutional and stakeholders' role on the transportation activity itself, the role of citizens on transportation system must also be understood. Assuming that elements of society (e.g. economic wellbeing, environmental conditions and social integration) can be affected by the transport planning, a citizen's role is added to the contemporary transport planning process.

The fourth element regards predictions of outcomes, based on the options, which are based on the goals and objectives. This stage of the process is still dependent on models, however, not only considering the traditional models, but also more activity-based, in spatial and temporal scale. Thus, the participation of demographic and social data has been increasing in mathematical models. Most of the transport planning outcomes consider mainly monetary aspects; however, it can also consider visual impacts, environmental dislocations and employment impacts.

The fifth element is related to the selection of a course of action. At this point of the planning process, there are the considerations of costs and benefits. However, this stage should also consider a public consultation, although the final decisions are usually made by politicians who, consequently, tend to give more attention to transport professionals and pressure brought by citizens' groups.

Table 3: Main differences between Traditional and Contemporary Transport Planning

Elements	Traditional Transport Planning	Contemporary Transport Planning
Objectives	Prediction of traffic flow	Prediction of traffic flow Environmental impacts Socioeconomic impacts Socio-spatial impacts
Methodologies	Four-stage process	Quantitative methods Qualitative methods
Goals	Attend demand	Attending demand Social equity Improving safety and health Reduce emission of pollutants Improve community liveability Enhancing economic opportunities Promote sustainable mobility

Source: adapted from Rodrigue et al. (2013, pp. 280-303)

Table 3 gives an overall point of view of the main elements that differentiate the traditional and contemporary transport planning. More objectively, it is possible to observe that contemporary transport planning can consider many objectives, combining interests (social, economic and environmental). Methodologies of evaluation of contemporary transport planning can vary from quantitative and qualitative methods, or even a combination of both. Furthermore, the goals can be more extensive, depending on the objectives. A contemporary transport planning may require a multidisciplinary team, in order of the selected way (set of options) to deal with the objective(s). Another important issue is to understand the order of decision, regarding who is responsible in engaging (start) the transport planning.

According to Gonçalves (2014), the transport planning process is usually a responsibility of the government (in national, state or municipal scale). The type of governance can influence the dynamics of the transport planning, regarding the share of responsibilities among political levels and how society is (or not) included in this process (Gonçalves, 2014). Therefore, the transport planning process can be guided differently, depending on the city, in order of the different institutes, governance levels, levels of participation in the planning process and different regulations within each city. Besides the elements related to the praxis of the transport planning process, there is the political stance, which brings a complexity to the planning process, as is shown in Figure 27 (Gonçalves, 2014, p. 114).

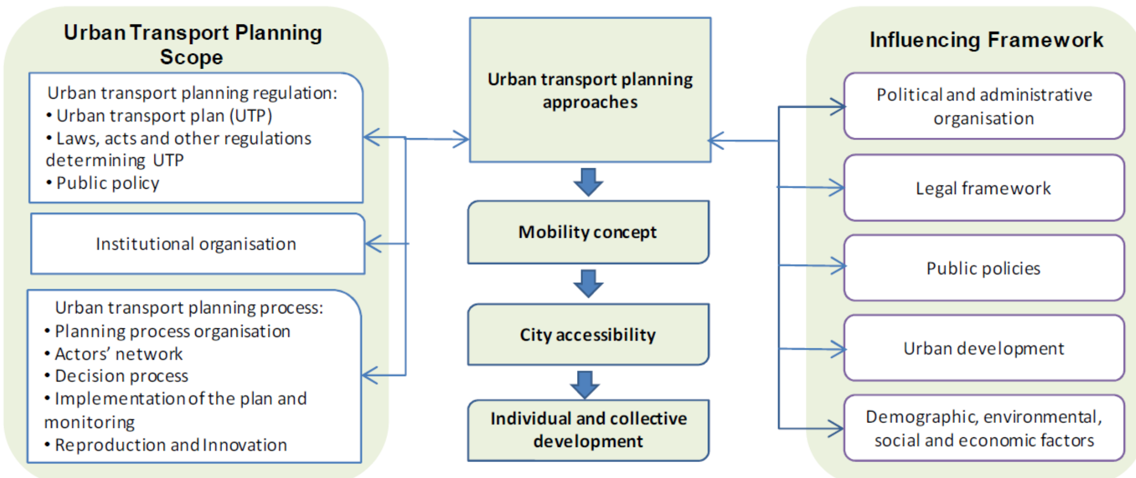


Figure 27: Integrated urban transport planning approach towards accessible cities for individual and collective development: scope and influencing framework (Gonçalves, 2014, p. 114)

Figure 27 is an overall view of the urban transport planning process, as a complex system, which involves public and private scale and can influence social, economic and environmental factors (Gonçalves, 2014). The urban transport planning is an object that can generate extensive studies, regarding its process and influences. Other important issues are the investments and timing of the urban transportation process.

According to Vasconcellos (2014a), there is an action time for the planning processes. The urban planning is classified as a long-term process, transport planning as a middle term and traffic management as a short-term process. A long-term process can take until 20 years, while a short-term can take up to one week.

For a more specific view of the time estimation, considering planning and implementation, Figure 28 presents an average of the time estimation of transport planning process for high capacity public transport. Based on this figure, it is possible to observe that, depending on the type of transportation system intended, the process can take from, approximately, five to 20 years to finish. Therefore, a transport planning can reach a long-term process, being equivalent (in time estimation) to an urban planning process.

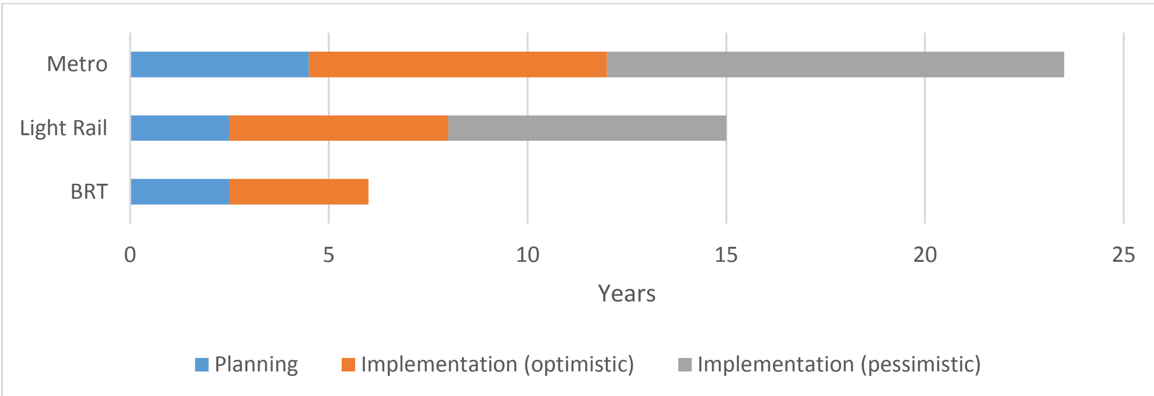


Figure 28: Average time estimation of planning and implementation of high capacity public transport (metro, light rail and BRT systems) (Source: adapted from Gonçalves (2014) and ITDP (2007))

Wegener (2004) classifies urban change processes in the speed of change categories: very slow change; slow changes; fast change and immediate change. These changes happen in nine subsystems, which are urban transport; land use; workplace; housing; employment; population; goods transport; trips (e.g. work, leisure or shopping); and urban environment. The ones that are classified in the very slow changes are urban transport (network and infrastructure) and land use; workplaces and residential areas are classified as slow changes; changes in employment and population are considered fast; goods transport and travel are considered to have immediate changes (Wegener, 2004). From a simple overview, Wegener (2004) considers the changes related to physical infrastructure (buildings and transport systems) as slow and those that are related to immediate human action (e.g. car ownership; changing of household or jobs; traffic conditions) can be fast or immediate.

Urban environmental impacts are a more complex subsystem of the urban processes, because each type of impact can be classified in a different speed of change (Wegener, 2004). For example, transport noise and air pollution are immediate impacts, while water and soil pollution are built up over time. There are also the long-term climate effects, which are identified with difficulty (Wegener, 2004). Therefore, it is understood that the time span of the urban planning process is presented in different levels, from the planning to implementation, and in the social and environmental level, regarding new behaviour patterns and environmental impacts. Besides the time span, regarding urban planning and implementation, there is also the monetary aspect (how much money is invested).

As an example, it is known that the implementation of Bus Rapid Systems (BRT) have been increasing in many cities of the world, in order of the successful results in the municipality of Curitiba, a city in Paraná, Brazil (ITDP, 2007). Two reasons are explored here, which contribute to the expansion of this type of transport system in other cities of the world, such as the time span of implementation (shown in Figure 28) and its costs.

From the cost perspective, it has been identified that the implementations' cost of BRT can range from US$1 million to US$3 million, according to the size and complexity of the city (ITDP, 2007). In relation to other transport systems, the BRT system can cost four to 20 less than a light rail systems, and 10 to 100 times less than a metro system (ITDP, 2007). Besides the implementation costs, there is the operation cost, which usually includes repayment of capital (e.g. vehicle depreciation and cost of capital), fixed operating costs (e.g. driver salaries, administrative costs, insurance) and variable operating costs (e.g. fuel, parts, and maintenance) (ITDP, 2007).

This section highlighted the role of transport policies, how it evolved from an overall perspective. Furthermore, this section also discusses about transport planning process, regarding the elements considered in early and contemporary processes of urban transport planning. This planning process is seen as complex, because although it can have defined technical processes of planning and implementation, it also deals with political aspects, such as regulations (laws and policies) and hierarchical order of decision-making. Other important elements within this process are the investment required and time span, which also can be reflected in the set of options of the decision-makers.

Despite the fact that the urban transport planning process involves a complex set of elements until it gets to the implementation stage, it is understood that the transport policy, usually, serves to orientate the planning process to provide society with better conditions of mobility, considering economic, environmental and social aspects. However, this section reviewed the process itself, instead of reviewing the transportation and mobility from a sociological point of view, which is the objective of the following section.

3.3. Urban Transportation: The Socio-spatial Approach

This section locates the sociology approach in urban studies. After identifying this approach, the focus is on the approach towards urban transportation. The elements identified support the framework of the resilience of urban mobility, as the previous and following approaches, which are discussed in this thesis.

3.3.1. Urban Sociology: a Review on Elements and Approaches

Urban sociology is considered as one of the precursors in the field of modern social science (Castells, 2002). Urbanisation, population growth, economic development, social mobility and struggle are the origins of urban social studies. Urban social studies gained more visibility in the 20th century, through the Chicago School of Urban Sociology (Scott & Storper, 2014; Castells, 2002; May & Perry, 2005).

The studies of Chicago School in the early 20th century until the 1950s, focussed on urban culture with the objective of understanding the social relations within the complexity of the urban environment (Lutters & Ackerman, 1996; Castells, 2002). This School adapted ecological models into the approach of understanding the urban social relations, which meant dealing with social patterns from a social-Darwinist approach (known as human ecology) (Castells, 2002; Lutters & Ackerman, 1996). According to Castells (2002),

> *…the study of forms and processes of human settlements under the notion of competition and social selection, and the analysis of the social conditions for cultural integration, were the founding themes of an urban sociology that, while ideologically biased, responded to the historical issues raised by industrialization and urbanization in the first half of the twentieth century. (Castells, 2002, p. 10)*

Although scholars started to question the Chicago School approach, for instance, the assumption of a homogeneous social structure, by not regarding, for instance, class, gender and ethnicity of a society, it is acknowledged that this School established a more rigorous scientific approach on social analysis, when comparing the early sociologists' research (Castells, 2002; Lutters & Ackerman, 1996).

According to Castells (Castells, 2002), the urban problems that originated in the studies of the Chicago School (mainly, social/cultural integration), were not the main issues in the 1960s and 1970s. They were initiated because of the interest of scholars towards the issues related to the developing problems of the urban industrial society (Castells, 2002). Furthermore, within this society, other issues which were (and still are) included in the social studies were the social movements and the notion of development compared to the relationship between economic growth, society and nature (Castells, 2002). In a more specific view, urban social studies started focussing more on the effects of social services and public amenities on the daily life of urban citizens and urban processes; in other words, searching for the understanding of the state intervention in peoples' lives (Castells, 2002). This approach is named as the "new urban sociology".

There are four main themes currently dominant in urban sociology (Castells, 2002). These are as follows: (1) production of space (Castells, 2009; Carlos, de Souza, & Sposito , 2011; Lefebvre, 2008; Soja, Morales, & Wolff, 1983; Lefebvre, 1991; Molotch, 1993); (2) the right to the city (Harvey, 2003; Lefebvre, 1995; Harvey, 2012); (3) collective consumption (Castells, 2002; 1983; Walton, 1993); and (4) urban social movements (Castells, 1983; Harvey, 2012).

3.3.1.1. Production of Space

Regarding the first theme, production of space, there is an extensive literature on the understanding of how urban space is produced and how it works as social construction. Castells (2009) developed a research, which he builds as an understanding of the urban space, based on the historical relationship between space and society. Through this perspective, he defines the city as a geographical place with a political-administrative structure implemented in the society. This reaches a technical and social (natural and cultural) development level, in a way that there is a differentiation of the product in a simple and broad labour force, reaching and exchanging systems of distribution and exchange, which supposes the existence of the following (Castells, 2009, pp. 42-43):

(1) a system of social classes;

(2) a political system, which allows, at the same time, the functioning of the social set and the dominion of a social class;
(3) an institutional system of investment regarding, mainly, what involves techniques and culture;
(4) a system of exchange with the external.

Considering this definition and its elements, Castells (2009) reviews, through a historical perspective, cities from the Roman Empire period, medieval age, spanning to the industrial period. In these three periods, he identifies the elements within the concept presented. His highlights regard the industrial period, which is differentiated from the other periods, because of the development of the industrial capitalism, leading the turning of commodities into the main engine of the economic systems, technical and social division of labour, division of the social and economic interest within space and the generation of a homogenous institutional system. This process is also called "commodification" (Thrift, 2006). Furthermore, this process brought the bourgeoisie to a dominant position.

The urbanisation related to the first industrial revolution and within a capitalist production is a spatial organisation process that relies on two fundamental facts (Castells, 2009, p. 45). The first deals with the dissolution of agrarian social structures and the mobility of the population to existing urban areas, thus providing essential labour force for industrialisation. The second is the strengthening of domestic economies, towards a manufacturing economy, than a fabric economy, which leads to a concentration of labour force and creation of a consumers' market, which are constituents of the industrial environment.

From these fundamental facts, it is possible to affirm that the urbanisation process after the first industrial revolution, had, basically, two ways of proceeding (Castells, 2009). They are as follows: (1) the already established city would attract industries, because of the presence of labour force and market, which leads the city to the industrial capitalism logic; (2) if a place has raw material and good transportation conditions (in implementation or already implemented), the industry would colonise this place and consequently, induce urbanisation.

The technical improvements of the second industrial revolution were the roots for the rise of the metropolitan regions (Castells, 2009). For example, the introduction of new means of production and consumption, the reduction of the obstacle “space” with the introduction of new means of communication and transportation.

Regarding transportation issues, Castells (2009) adds that public transportation allowed the integration of different zones and activities in metropolitan areas, distributing the internal flows according to the tolerable space-time relation. Furthermore, in these issues, private automobiles contributed to an urban spreading, with enormous individual residential zones linked to the express circulation routes in direction of different functional sectors of the metropolitan region.

With the technological improvements of the second industrial revolution (e.g. civil construction, energy and transportation), the industrial sector established a dependent relationship on the complex system of the city, because its locational criteria were no longer the functional elements (raw material and ease of material flow), which were characteristic of the first industrial revolution (Castells, 2009). However, the technical improvements are not the only factors of the metropolitan formation (Castells, 2009).

According to Castells (2009), space and technology constitute a material bond between the set of social structure and the new urban form. From this perspective, the spreading of the urban area is closely related to social capitalism. Because the same logic by which the social classes are structured, the activities in space are also structured, specifically moulded through a functional zoning within the metropolitan area (Castells, 2009).

Urban society, through the anthropological view, is a system of value, norms and social relations with its own history and transformations (Castells, 2009). In other words, the urban society can be defined as a specific system of social relations (Castells, 2009). From this perspective, to understand the urban space, there must be some level of use of a general social theory (Castells, 2009).

Towards a spatial analysis, Castells (2009, pp. 181-199) considers a base line theory of social organisation, for which he considers two essential principles: (1) the principle of interdependence between invidious; and (2) the principle of central function.

The first principle is based on the symbiotic and commensalism relations, where there is a complementary difference and supplementary similarity (Castells, 2009). The second principle considers that every relational system within an environment secures the coordination by an intermediary of a small number of central functions (Castells, 2009).

The society in the urban space can be defined as a relational system between parts, which are functionally differentiated and territorially located (Castells, 2009). Furthermore, the urban organisation as a set of processes, moulds, distributes and correlates the "ecological units" (Castells, 2009, pp. 181-199). According to Castells (2009, pp. 181-199), there are six main ecological processes within the city: (1) concentration; (2) centralisation; (3) decentralisation; (4) circulation; (5) segregation; and (6) invasion-succession, which include the following:

(1) Increase of the population density in a certain space and time period;
(2) Functional specialisation of a certain activity or activity's network in the same space, with its hierarchical articulation in a territorial set;
(3) The mobility of the urban structure;
(4) Circulation in a broad sense: movement of people, goods and information;
(5) The process in which a social content is homogenised in a certain unit of space and differentiates itself from external units of space, regarding social stratification distance;
(6) This regards the process in which a new population or activity is introduced to a space that is already occupied. The new is rejected by the previous occupation. However, the new succeeds or integrates as being dominant in the aimed space unit.

For Castells (2009), there is a need to understand the urban space beyond the logic that only space explains the social conditions or distribution. The ecological perspective of urban space has further fundamental value, when the central issue is the contradiction of the social agents (social classes) (Castells, 2009). In other words, the understanding of the accumulated sociocultural correlations leads to the productive forces and, consequently, the productive relations, which rises from them (Castells, 2009). These correlations articulate the production of space and social structure (Castells, 2009).

Therefore, urban space can be viewed as a historical articulation of the various means of productions, which are defined as the fundamental practices of the social structure, through three aspects (Castells, 2009, pp. 181-199). These aspects are as follows: (1) economic; (2) political-institutional; and (3) ideological, which include the following:

(1) The economic aspect deals with the support of determined productions' means, transforming urban space in order to produce the conditions of social existence, by determining the laws of the means of production (Castells, 2009, pp. 181-199). Furthermore, the spatial expression of this economic system can be identified through four main elements (Castells, 2009, pp. 181-199). They are as follows: productions (e.g. industry and offices); consumption (e.g. residence and public installations); exchange (e.g. circulation and trade); and management (e.g. municipal management and urbanism plans);
(2) The spatial expression of the political-institutional aspect is determined by the division of space (e.g. administrative division and neighborhood) and economic organisation (issues related to management) (Castells, 2009, pp. 181-199);
(3) The nature of urban contradictions (social) (Masson & Mainardes, 2011; Castells, 2009, pp. 181-199; Feldman, 1978).

Based on Castells' (Castells, 2009) theoretical background, the organisation of social space can be understood from determining spatial forms: through each aspect; the combination of these aspects; the persistence of spatial forms, induced by the previous social structures; and through the different actions of individuals or social groups.

3.3.1.2. The Right to the City

There has, recently, been a in the social approach regarding *the right to the city* (Harvey, 2008; 2003; Plyushteva, 2009; Lefebvre, 1995). According to Harvey (2008):

> *The right to the city is far more than the individual liberty to access urban resources: it is a right to change ourselves by changing the city. It is, moreover, a common rather than an individual right since this transformation inevitably depends upon the exercise of collective power to reshape the process of urbanization. (p. 23)*

Harvey's quote (2008) follows the same logic of urbanisation, understanding it as a product of a class phenomenon, under the conditions that from somewhere and somebody, the surpluses are extracted. From this perspective, the development of capitalism has a close connection with urbanisation (Harvey, 2008).

The politics of capitalism is shaped by the continuous need to find profitable ground for capital-surplus production and absorption (Harvey, 2008).The capitalist logic leads to the search for new means of production and for natural resources, putting pressure on the natural environment

(Harvey, 2008). These main elements can be also interpreted as barriers to capitalism, because they can disable the reinvesting of surplus product (Harvey, 2008).

Through the understanding of two examples, from France and United States, Harvey (2008) argues that urbanisation plays an important role, regarding the absorption of surplus product "that capitalist perpetually produce in their search for profits" (p. 25).

The first example is that of the Second Empire Paris, in 1848, when unemployment surplus and surplus labour crises were widespread in Europe (Harvey, 2008). Paris severely suffered from unemployment and with this event, the unemployed workers and the bourgeois class engaged in a movement, which "saw social republic as the antidote to the greed and inequality that characterized the July Monarchy" (Harvey, 2008, p. 25). However, Louis-Napoleon Bonaparte ascended to power, proclaiming himself as the Emperor (Harvey, 2008).

In order to recover from the jeopardised economy and solve the surplus-capital and unemployment, a program of infrastructural investment at the European and local level was initiated (Harvey, 2008). The investments within the European scale were forwarded to railroad construction throughout Europe and the Orient, along with the implementation of the Suez Canal (Harvey, 2008). Within the Paris scale, the infrastructural investments were focussed on the railway network, building ports and harbours and draining marshes (Harvey, 2008).

According to Harvey (2008), the transformation of the urban infrastructure was not only a physical change of the city but also generated a new urban way of life. Thus, Paris became the centre of consumption, tourism and pleasure, with cafes, department stores and the fashion industry (Harvey, 2008). These expanded functionalities absorbed "vast surpluses through consumerism" (Harvey, 2008, p. 26). However, in 1868, a financial crisis arose, which was one of the factors that induced Napoleon to go to war with Germany (which he lost) (Harvey, 2008). This fact gave rise to the Paris Commune, which claimed for rights to improve the living conditions of the working class and to gain access to what the capitalist logic was depriving them of (Harvey, 2008).

In the case of the United States, Harvey (2008) describes the case of New York, which suffered from the 1929 financial crisis, leading the American population to suffer from a massive unemployment process. After the Second World War, with the objective of absorbing capital surplus, the same changes applied in Paris were applied to New York, around the 1850s (Harvey, 2008). Changes were based on investing on highway systems, infrastructural transformations and suburbanisation, not only in the city, but also in the metropolitan area (Harvey, 2008). Thus, according to Harvey (2008):

> *As in the Second Empire Paris, it entailed a radical transformation in lifestyle, bringing new products from housing to refrigerators and air conditioners, as well as two cars in the driveway and an enormous increase in the consumption of oil. It also altered the political landscape, as subsided home-ownership for the middle class changed the focus of community action towards the defense of property values and individualized identities, turning the suburban vote towards conservative republicanism. (p. 27)*

However, the end of the 1960s was represented by a discontent, leading the middle class to search alliance with the marginalised groups to claim for civil rights and against American imperialism (Harvey, 2008). Furthermore, in 1973 and 1975, the capitalist system crashed, reflecting the critical moments of capacity to absorb surpluses (Harvey, 2008). Under this context, Harvey (2008) affirms that Lefebvre wrote *The Urban Revolution* (Lefebvre, 2008). Under Harvey's interpretation of Lefebvre (2008), he believes that, in this context:

> *The right to the city had to mean the right to command the whole urban process, which was increasingly dominating the country-side through phenomena ranging from agribusiness to second homes and rural tourism. (p. 28)*

Considering regional crises and crashes, e.g. East and Southeast Asia in 1997–98; Russia 1998; Argentina 2001; United States in the 1990s, the question that Harvey (2008) poses is: what is the role of urbanisation in stabilising social conflicts and capital-surplus problems?

In the case of the United States, the property market served as an economic stabiliser after the crash of the late 1990s (Harvey, 2008). The housing sector reflected in the construction of homes and offices in cities' centres and suburbs, thus absorbing the capital surplus (Harvey, 2008). This process also increased the domestic market of the US, by boosting the consumption of goods and services (Harvey, 2008). However, for the US, the price marched into a trade deficit, by borrowing two billion dollars to maintain "consumerism and the wars in Afghanistan and Iraq" (Harvey, 2008, p. 29).

In the 1990s, Britain, Spain and other countries also had some urban changes through the property market boom (Harvey, 2008). However, in the case of China, there was a strong investment in the infrastructural development, including dams and highway projects (Harvey, 2008). Developing countries, such as Brazil and Chile, recovered their economies in part by China's demand for raw materials (Harvey, 2008).

The point that Harvey is getting to, regards the low-income classes. He exemplifies the case of the US, where these classes are the most affected, because they cannot afford house prices in urban centres, forcing them into metropolitan semi-peripheral areas, where there is access to lower prices (Harvey, 2008). However, they are also exposed to "escalating commuting costs as oil prices rise, and soaring mortgage payments as market rates come into effect" (Harvey, 2008, p. 31).

With the transformation of the urban infrastructure along the years, the urban lifestyle also changed, turning the quality of life into a commodity, as the city itself (Harvey, 2008). This means "consumerism, tourism, cultural and knowledge based industries have become major aspects of the urban political economy" (Harvey, 2008, p. 31). This context is also reflected in the urban spatial forms, through fortified fragments, gated communities and privatised public spaces (Harvey, 2008). These urban transformations are usually followed by the expropriations of the low-income classes, from places, where valuable land is available (Harvey, 2008).

In Mumbai, for instance, there is a slum (Dharavi), which has an estimation of two billion dollars (Harvey, 2008). There is a pressure to clear this area, under environmental and social arguments, which, in fact, masks a capital interest (Harvey, 2008). Regarding this matter, Harvey (2008) asks and answers:

> *Will the people who are displaced get compensation? The lucky ones get a bit. But while Indian Constitution specifies that the state has an obligation to protect the lives and wee-being of the whole populations, irrespective of caste or class, and to guarantee rights to housing and shelter, the Supreme Court has issued judgements that rewrite this constitutional requirement. Since slum dwellers are illegal occupants and many cannot definitively prove their long-term residence, they have no right to compensation. (p. 35)*

This type of government action presented in the quotation above can be seen in the developing and developed countries. However, depending on the country and situation, the benefits of those who lose the land can vary from nothing to something (significant or probably not). In China, for instance, the lack of private property leaves the population vulnerable, meaning that the state can remove them at any time (Harvey, 2008). The places in China, which suffer more with these actions, are the rural margins (Harvey, 2008). Furthermore, Harvey (2008) illustrates:

> *...the significance of Lefebvre's argument...that the clear distinction which once existed between the urban and rural is gradually fading into a set of porous spaces of uneven geographical development, under the hegemonic command of capital and the state. (p. 36)*

Based on the presented arguments, Harvey (2008) believes that urbanisation played a fundamental role in the absorption of capital surplus, through the processes of "creative destruction that dispossessed the masses of any right to the city whatsoever" (p. 37). According to Harvey (2008), the increasing rise of social movements plays a significant role to the underprivileged in their demand for the right to the city. Furthermore, he believes that to achieve the right to the city, they should demand for "greater control over the production and utilization of the surplus" (p. 37).

3.3.1.3. Urban Social Movements and Collective Consumption

Castells (1983) aims to understand "how urban movements connect collective consumption issues with cultural identity and political power" (p. 342) with the objective of building a theory of urban social movements. He assumes the following hypotheses, to develop this understanding (p. 291):

1. "The city is a social product resulting from conflicting social interests and values; *(p. 291)*
2. Because of the institutionalization of socially dominant interests, major innovations in the city's role, meaning, and structure tend to be the outcome of grassroots mobilization and demands. When these mobilizations result in the transformation of the urban structure, we call them urban social movements; *(p. 291)*
3. Yet the process of urban social change cannot be reduced to the effect produced on the city by successful movements. Thus a theory of urban change must account both for the spatial and social effects resulting from the action of the dominant interests as well as from the grassroots alternative to this domination; *(p. 291)*
4. Although class relationship and class struggle are fundamental in understanding urban conflict, they are not, by any means, the only primary source of urban social change. The autonomous role of the state, the gender relationships, the ethnic and national movements, and movements that define themselves as citizen, are among other alternative of social change." *(p. 291)*

The perspective developed by Castells (1983) points out that the driving forces of urbanisation are not economy and technology. These two elements are determined by the social processes, which appropriate space and time; and, furthermore, construct social organisations that are constantly "challenged by the production of new values and emergence of new social interests" (Castells, 1983, p. 291). Castells (1983) believes that urban change is linked to the conflict between:

> *…social classes and historical actors over the meaning of urban, the significance of spatial forms in the social structure, and the content, hierarchy, and destiny of cities in relationship to the entire social structure. (p. 302)*

Therefore, Castells (1983) regards society as a structured and conflictive reality, which each social class opposed to each other, through its own interest and values, influencing the social organisation. The urban space is a material representation of the social structure, which is apparent through economic, religious, political and technological operations (Castells, 1983).

According to Castells (1983, pp. 291-336), the urban form is determined by the urban meaning and urban function. (1) Urban meaning, (2) urban function and (3) urban form are defined as follows:

1. "The structural performance assigned as a goal to cities in general (and to a particular city in the inter-urban division of labor) by the conflictive process between historical actors in a given society" *(Castells, 1983, p. 303)*;
2. "The articulated system of organizational means aimed at performing the goals assigned to each city by its historically defined urban meaning" *(Castells, 1983, p. 303)*
3. "Symbolic expression of urban meaning and of the historical superimposition of urban meaning (and their forms) always determined by a conflictive process between historical actors" (social classes) *(Castells, 1983, p. 303)*.

Based on these definitions, Castells (1983, pp. 291-336) presents three processes that shape the city:

1. "Conflicts over the definition of urban meaning" *(Castells, 1983, p. 303)*;
2. "conflicts over the adequate performance of urban functions" *(Castells, 1983, p. 304)*;

3. and “conflicts over the adequate symbolic expression of urban meaning and (or) function” *(Castells, 1983, p. 304)*

From these three processes, Castells (1983, p. 304) understands urban social change as the redefinition of urban meaning; urban planning as the negotiated adaptation of urban functions to a shared urban meaning; and urban design as the symbolic attempt to express an accepted urban meaning in a certain urban form.

Furthermore, Castells (1983, p. 304) believes that the urban social change is generated through the production of a new urban meaning, specifically by four processes, “all of them conflictive and in opposition to one or more historical actors” (Castells, 1983, p. 304), which may or not be linked:

1. “The dominant class in a given society, having the institutional power to restructure social forms (and thus city) according to its interest and values, changes the existing meaning” *(Castells, 1983, p. 304)*;
2. “A dominated class accomplishes a partial or total revolution and changes the meaning of the city” *(Castells, 1983, p. 304)*;
3. “A social movement develops its own meaning over a given space in contradiction to the structurally dominant meaning” *(Castells, 1983, p. 305)*;
4. “A social mobilization (not necessarily based on a particular social class) imposes a new urban meaning in contradiction to the institutionalized urban meaning and against the interest of the dominant class” *(Castells, 1983, p. 305)*.

Castells (1983) differentiates between the capitalist mode of production and the mode of development. Mode of development is related to the specific form in which labour, matter and energy are combined in work to obtain the product, while the capitalist mode of production aims to maximise profit (Castells, 1983, p. 307).

Castells (1983) presents two types of development modes: industrial and informational. The industrial mode regards the productivity as a result from an increasing quantity of labour, matter and energy (from one, two or all together). The informational mode is related to knowledge-based productivity and results from the organisational methods of combining the three elements of production (labour, matter and energy) (1983). Furthermore, Castells (1983) affirms that:

> *The capitalist mode of production and the industrial and informational modes of development are territorially differentiated and integrated at the world level in an asymmetrical matter (p. 310)*

Castells (1983) explains that core-peripheral relations can be different, depending on the field of analysis (e.g. energy, finance, car production or research into microelectronics). In other words, there are various levels of inter-relationships, which can shift from time and dimension. From this perspective, it is visible that there is a global system of dependency between societies, in different levels of time, space and scale.

Moving to the issue of power, according to Castells (1983), the nation-state still holds the power, which makes society dependent, avoiding the disintegration, through the mobilisation and construction of the nation to impose new relationships between core (or centre) and periphery. Through this observation, he presents the social challenge within the worldwide capitalist production context, of the power relationship between states:

1. "First from the resistance to foreign domination by national cultures"; *(p. 310)*
2. "Second, from the social mobilization generated in the periphery of the system by the new expansion of the industrial mode of development"; *(p. 310)*
3. "Third, from the new power relationship established between the super-states regulating the two modes of production that compete in today's world – capitalism and statism[6]" *(p. 310)*.

Under the theoretical bases presented by Castells until the above quotation, he explains that there is a strong intervention of the capitalist and statist modes of production on nation-states, in order to undermine human experience[7], consequently weakening social movements and their influence in changing the urban meaning. Therefore, Castells (1983) considers as his theoretical perspective, "the cities as being shaped by the outcome of social conflicts and contradictory projects" (p. 318).

[6] "By statist mode of production, we mean a system where the appropriation of surplus from the producers is based upon the political domination of a state apparatus, itself controlled by a self-reproducing elite relying on the monopoly of violence and means of information" (Castells, 1983, p. 306).

[7] Which can be interpreted as the equal opportunity of social classes to have control of production and benefit from capital surplus (Harvey, 2008).

Spatial forms and functions are determined by the history of conflicts between social classes. As way to visualise this logic, Castells (1983) presents four socio-spatial processes that demonstrate the transformations of urban meaning through the industrial mode of development observed in cities from Europe, North America and Latin America:

1. "The concentration and centralization of the means of production, units of management, labor power, markets, and means of consumption in a new form of the gigantic and complex spatial unit known as metropolitan area" *(p. 312)*.
2. "The specialization of spatial location according to the interests of capital and to the efficiency of industrial production, transportation and distribution" *(p. 312)*.
3. "The commodification of the city itself, both through the real estate market (including land speculation) and in its residential areas triggering, for instance, suburban sprawl as a way of opening up construction and transportation markets, and of creating a form of household designed to stimulate individualized consumption" *(p. 312)*.
4. "The basic assumption that the accomplishment of this model of metropolitan development necessitated the mobility of the population and resources, shifting to where they were required for profit maximizing. This assumption followed massive migration, disruption of communities and regional cultures, unbalanced regional growth, spatial mismatching between existing physical stock and need for housing and facilities, and self-spiraling urban growth beyond the limits of collective efficiency and short of the minimum space-time requirements for the maintenance of patterns of human communication" *(p. 312).*

These processes reflect on generalised urban crisis in several aspects, such as housing, services and social control. Furthermore, the state copes with the urban crisis, in most cases (if not all) and leads to the politicisation of urban movements (Castells, 1983). He also observes that the response of dominant interest, under the urban crisis context, unfolds into two elements (or tools) (Castells, 1983): political (repression and integration) and technological (new systems of management and new techniques of production).

Regarding the informational mode of development, it creates new conditions for the restructuring of spatial form in crisis (Castells, 1983). The main impact is the "transformation of spatial places into flows and channels" (Castells, 1983, p. 312) (e.g. online shopping).

With the background presented by Castells (1983), the experience of social movements and the influence on the urban meaning can be understood. For Castells (1983), urban movements are acts that express social conflicts, which reflect on what urban meaning is, what they want it to be and why (interests). Furthermore, urban movements, which materialise their values and interest, are structured on three basic goals[8]:

1. Improve collective consumption, within the logic of exchange value, which can be represented, for instance, by the demand of "housing provided as a public service, the preservation of a historic building or demand for open space" (Castells, 1983, p. 319). The notion of collective consumption contradicts the notion of the "city for profit in which the desirability of space and urban services are distributed according to the levels of income" (Castells, 1983, p. 319).
2. The second goal regards the "search for cultural identity, for maintenance or creation of autonomous local cultures, ethnically based or historically originated" (Castells, 1983, p. 319). Castells also defines this goal as the defense of communication between people, "against the monopoly of messages by the media, the predominance of one-way information flows" (Castells, 1983, p. 319). Urban movements with this goal, expose the discontent towards the standardisation of culture, from heteronomous sources.
3. The third goal is related to empowering the local government, neighbourhood decentralisation and self-management; "in contradiction to the centralized state and subordinated and undifferentiated territorial administration" (Castells, 1983, p. 320)

These goals of urban movements, plus the understanding of urban space as a product of social structure conflicts, bring Castells (1983, pp. 291-336) to reach a general a theoretical perspective, which is also represented in Table 4:

> *That cities and societies are produced by the conflictive process of collective actors mobilized towards certain goals, that is, way of structuring society and space. Therefore a movement is first of all defined by its goals (as expressed in its conscious practice) or set of goals* (Castells, 1983, p. 320)

[8] These goals can be understood as "purposive desires and demands present in the collective practice of the movement" (Castells, 1983, p. 319).

Table 4: The social structure underlying the dynamics of contemporary urban movements (Castells, 1983, p. 321)

Goal of the urban movement.	The city as a use value.	Identity, cultural autonomy and communication.	Territorially based self-management.
Ideological themes and historical demands included in this goal.	– Social wage. – Quality of life. – Conservation of history and nature.	– Neighbourhood life. – Ethnic cultures. – Historical traditions.	– Local autonomy. – Neighbourhood decentralization. – Citizen participation.
Goal of the adversary.	The city as exchange-value.	Monopoly of messages and one-way information flows.	– Centralization of power, rationalization of bureaucracy. – Insulation of the apparatus.
Social issues and ideological themes.	– Appropriation of land rent. – Real estate speculation. – Infrastructure for profitable capitalist production.	– Mass culture. – Standardization of meaning. – Urban isolation.	– Centralism. – Bureaucratization. – Authoritarianism.
Conflicting projects over the historical meaning of city.	City as a spatial support for life. *versus* City as a commodity or a support of commodity production and circulation.	City as a communication network and a source of cultural innovation *versus* Despatialization of programmed one-way information flows.	City as a self-governing entity. *versus* City as a subject of the central state at the service of world-wide. empires.
Structural historical contradiction of which the urban conflict refers.	Capital. *versus* Labour in the appropriation of surplus value and the decision over investment.	Information (excluding communication). *versus* Communication (that necessarily includes information).	Order and authority. *versus* Change and freedom.
Name of the adversary (historical actor).	Bourgeoisie.	Technocracy.	State.
Name of the urban movement by this particular goal (urban actor).	Collective consumption trade unionism.	Community.	Citizens.

The relationship amongst urban movements (their goals, cultural identity and political power), social changes, urban form, urban meaning and urban function is addressed in this section. From the understanding of this relationship, Castells shows a theoretical perspective of urban social changes through the urban movements. He also emphasises that urban social movements are not a new form of social change, but a physical representation of the conflict between social structures, which moulds the urban space.

Through Castells' point of view, it is not a matter of right or wrong, good or evil, but the understanding of this perspective aims towards the existence of an urban meaning based on a historical structural performance of social actors and conflicts between them. Therefore, in a certain space there are dominant values, which reflect on the urban functions, through the determination of urban meaning, which, consequently draws the urban form.

Through a cross analysis of the three main goals (or even one) of urban movements, identified by Castells, and the urban meaning, as it is, it is possible to see the ideological and structural conflicts, regarding the demand of what urban movements want urban meaning to be and how the adversary of urban movements act.

From the urban sociology's production of space, right to the city, urban movements and collective consumption, it is possible to observe the interceding point, which is the social production of space. Through the constructed notion of the discussed themes, the intention for the next section is to understand how these reviewed topics can or cannot be related with transportation and urban mobility.

3.3.2. The Sociology of Urban Transportation

This section analyses aimed works on transport sociology, and then discusses what they are, considering or not, based on the urban sociology groundings. Furthermore, it can be said that the field of sociology of transportation is not so explored; the technical approach is still dominant on urban transport researches (Vasconcellos E. A., 2014a). Few works were found, which addresses, directly, the sociology of transportation, such as Yago (1983), de Boer (1986), Vasconcellos (2014a) and Vannini (2010).

Vasconcellos (2014a) explains why there are a few distinguishing sociological transport from descriptive social researches. According to him, the descriptive social research is based on social impacts; and the sociological approach focusses on the relationship between travel patterns and social, political, economic and institutional constraints. More specifically, the sociological approach analyses transport and traffic-related social data in respect to the relative economic and political assets of social groups and classes, as well as their conflicting (or merging) interests (Vasconcellos E. A., 2014c). Therefore, from this definition, he identifies few works based on the sociological approach.

According to Vasconcellos (2014c), the term "sociology of transport" can be seen as a drawback, because the term itself does not locate the users as active elements, whether passive or not, which is not his objective. Therefore, he proposes using the term "sociology of circulation", within which there is the “circulation structure” and “circulation means”. The first term regards the highway, railways, streets, pavements and terminals; and the second term regards the vehicle (which he interprets as the human body, as well as non-motorised and motorised vehicles).

To Vasconcellos (2014c) the supply, operation and appropriation of urban transportation are organised through a cooperative or competitive basis, by the state, private economic agents and social groups. Furthermore, Vasconcellos affirms that the “[D]ecisions of supply, operation and appropriation are constrained by political, economic, social and cultural factors, which vary remarkably in time and space” (2014c). Based on his sociological review, he assumes that the central issues of transport and traffic policies are as follows:

- How access is distributed in space? *(2014c)*;
- How different social classes and groups use the city? *(2014c)*;
- What the related conditions of equity, safety, comfort, efficiency, environment and cost are? *(2014c)*.

In addition to these issues, Vasconcellos (2014c) acknowledges Castells’ perspective of urban sociology as a basis to develop the understanding of the “sociology of circulation”, as he proposed. From his perspective, the sociological study of transport should consider the contradictions between the internal logic of a traffic system and the historical perspective of social contradictions, within the segregation trends of the capitalist urban development.

In order to clarify the differences between the technical, social and sociological perspective on transport studies, Vasconcellos (2014c) presents an example to show how it would be regarded through each perspective. The example he chose was traffic safety problems and the approaches are exemplified in Table 5.

Table 5: Difference between prevailing and proposed approaches to transport

Approach	Typical factors considered in the analysis (example)	
	Transport quality	Traffic accidents
Technical	Vehicle traffic conditions (volume, speed, density)	Number of accidents by type
Social	Vehicle traffic conditions and quantity of people involved	Accidents by type and characteristics of people involved (age, gender)
Sociological	Vehicle traffic conditions and quantity of people involved, analysed in the light of their social and economic characteristics and their access to different transport means	Accidents by type and characteristics of people involved (age, gender) analysed in the light of their social and economic characteristics, their behaviour, their level of education

Source: Vasconcellos (2014c).

Observing Table 5, Vasconcellos (2014c) explains that a technical analysis tries to represent the problem in quantitative terms, through speed, density and volume data with the objective of providing enough space and traffic conditions for the demand. The technical approach focusses on the vehicles, instead of the people.

The social approach complements the technical analysis by collecting social data, such as how many people are travelling and social characteristics of those under the impact of traffic safety (such as age and gender) (Vasconcellos E. A., 2014c). Vasconcellos (2014c) adds also that the social approach can allow an initial understanding of the division of space between people.

The sociological approach, according to Vasconcellos (2014c), adds to the social and technical data (qualitative and quantitative):

> *…any information on the social and economic characteristics of people travelling on each mode, their actual access conditions to each mode, and the political determinants of transport and traffic policies that surround the issue (2014c)*

Considering this sociological approach, it would be possible to analyse the reason why space is divided in the prevailing way, in other words, the motive that some people have or not have access to certain transport modes, and how externalities are generated and experienced by those involved with the transport or traffic problems under analysis (2014c):

> *Therefore, the sociological approach never sees manifest demand as a given, but rather as a product of prevailing conditions, influenced by individual and family characteristics, the existent transport systems, spatial and time constraints, and public policy decision (2014c).*

Through this understanding of the sociology of transportation (or circulation), Vasconcellos (2014c) proposes a sociological approach on transportation, which considers four mains points:

1. "The analysis of the trip patterns, the social structure, and the general constraints that affect the user's choices" *(2014c)*;
2. "The examination of the transport deprived and the very concept of deprivation" *(2014c)*;
3. "The analysis of social movements involved in transport issues" *(2014c)*;
4. "The analysis of the planning process itself and the characteristics of the social and political groups that directly or indirectly shape its content. This latter is also emphasized by Yago *(1983)*, who stresses the need to analyze the institutions and processes that constrain people's choices with respect to transport" *(2014c)*.

Assuming that people have to ensure the reproduction of society in order to continue living and participate in it (Vasconcellos E. A., 2014d), this reproduction process is dependent on several activities. They vary according to social, economic, cultural and political characteristics (Vasconcellos E. A., 2014d). Furthermore, Vasconcellos (2014d) adds that:

> *No movements corresponds to any sort of 'natural desire'…since all movements are related to the reproduction needs – dependent on individual and family characteristics and the social division of labor, and constraints by the dominant ideology (2014d).*

This reproduction of needs is represented in Figure 29. According to Vasconcellos (2014d), the reproduction of needs of an individual or a group is based on three sets of factors: (1) class, ethnicity and religion; (2) gender and age; and (3) life-cycles.

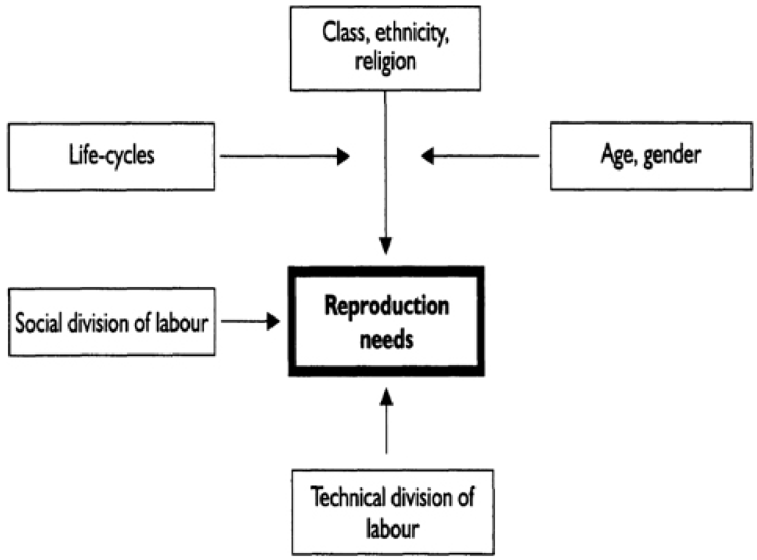


Figure 29: Elements influencing reproduction needs (2014d)

Regarding social class, this can be translated in terms of income, and political and educational assets; which can influence not only the reproduction of need, but also the transport behaviour, through the definition of activities and goals, defining which means of transport is also employed to achieve them (Vasconcellos E. A., 2014d). Religion and ethnicity have influence regarding mandatory activities or limiting other activities (Vasconcellos E. A., 2014d).

The dominant factors can vary from place to historical time. For example, class and income are dominant factors in a capitalist society, like religion in Islamic society or ethnicity in African societies (Vasconcellos E. A., 2014d). Furthermore, these factors combined can also be dominant and the combination can vary, depending on the place.

Another element that influences the reproduction is the life cycle and its internal characteristics (Vasconcellos E. A., 2014d). The life cycle regards the age structure of the family, for instance, if the family is composed of adults with children, or an adult couple or a household with adults, children and elderly (Vasconcellos E. A., 2014d). The gender influences reproduction and transport patterns through the division of tasks in the family (Vasconcellos E. A., 2014d).

Social and technical division of labour also influence reproduction and transportation patterns (Vasconcellos E. A., 2014d). The social division of labour is related to the different activities that an individual or a group exert within the society, while the technical division of labour is related to the requirements or training skills required for the exerted function (Vasconcellos E. A., 2014d). Furthermore, Vasconcellos (2014d) adds that:

> *Physically, most of these needs have to be fulfilled through transport between points in space, and the set of movements that will take place on a typical day forms the 'network' of the daily activities of each person (2014d)*

Vasconcellos (2014d) affirms that the network of activities of individuals or groups considers four main constraints: personal or family economic resources; personal or family time availability; the location and the operating hours of the desired activities; and the available transport means. From this theoretical basis, Vasconcellos (2014d) presents two events that occur with the individual or groups (also represented on Figure 30): (1) the mode of choice regarding available options and (2) the needs that cannot be fulfilled for any reason.

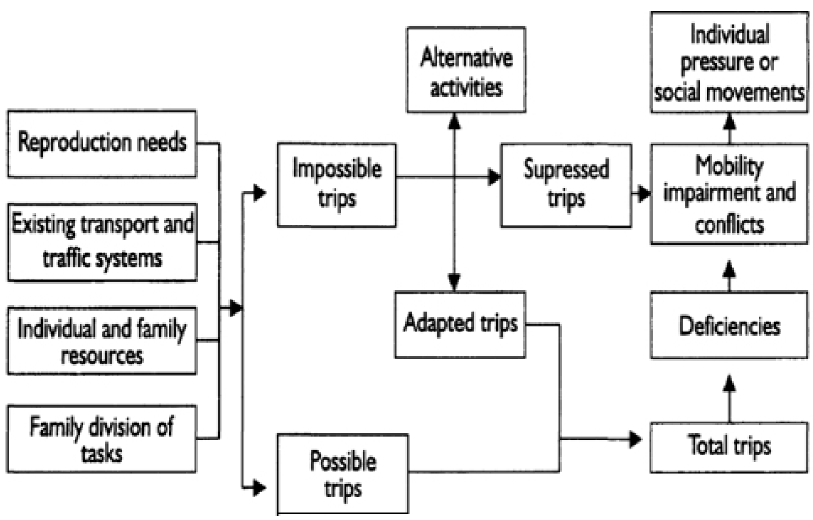


Figure 30: How transport demand pattern is formed (Vasconcellos E. A., 2014d)

The first event can be related to the feasible or possible trips and the second event regards the non-feasible or impossible trips (Figure 30). In addition to the second one, it can be replaced by alternative activities or suppressed indefinitely, both of which can lead to individual pressure or the rise of social movements (Vasconcellos E. A., 2014d). The set of feasible trips forms the Origin-Destination (OD) patterns. The mix of means of transportation (motorised or non-motorised modes) is closely related to the OD pattern. However, the action of performing the trip and choosing the transportation modes are a function, mainly, of the family (or individual) income and physical arrangement of the built environment (Vasconcellos E. A., 2014d).

As further observation, the transportation systems and circulation patterns are also subjected to a socio-spatial organisation, which is constantly being pressurised by social, economic and political elements and is in evolutionary change (Vasconcellos E. A., 2014d), as it is represented in Figure 31.

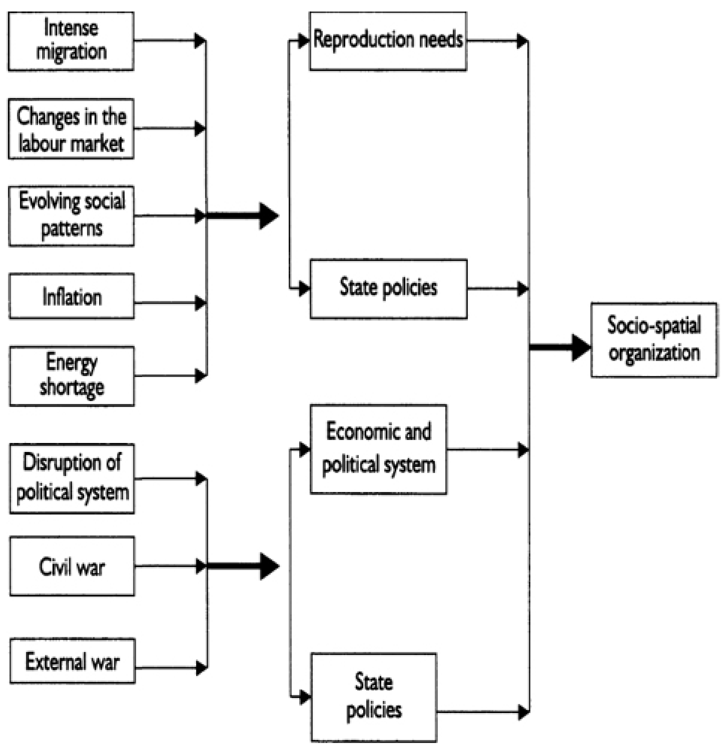


Figure 31: Structural and external factors influencing socio-spatial organisation (Vasconcellos E. A., 2014d)

Vasconcellos (2014d), exploring more specific reasons, presents three main sources of pressure on these systems (social-spatial organisation and transportation system). They are as follows: political dissatisfaction; urban and economic evolutionary changes and external changes in the economic or political environment. Vasconcellos (2014d) also presents the main causes of these pressures, as presented in Table 6.

Table 6: Causes of pressure on the socio-spatial organisation and transportation system

Pressures	Causes
Political dissatisfaction	"political dissatisfaction may arise from a daily experience of costly, uncomfortable or dangerous trips, or from a need to fulfil suppressed reproduction of needs"
Evolutionary change	"Evolutionary change can arise from the need to adapt space to economic development or migration, to accommodate changes in labor market (the feminization of labor) to cope with new reproduction needs (increase in schooling), or address catastrophic external influence (such as an energy shortage)"
External changes	"External changes may be caused by inflationary processes which limit or deny access to transport means or by a fiscal crisis, which may decrease state investment or support for the poor" and "may also be caused by sudden political disruptions that modify political alliances, and change state policies, and by war"

Source: adapted from Vasconcellos (2014d)

Vasconcellos (2014d) argues that depending on the political system and structure of the State, these pressures can influence the policies, changing the socio-spatial organisation or transportation system. According to him, pressures can be repressed or diverted; or negotiated, leading to a change in public policies, consequently restructuring the system.

In order to view the whole system, which Vasconcellos (2014d) presented, the diagram in Figure 32 joins all reviewed elements that can influence the social reaction towards circulation.

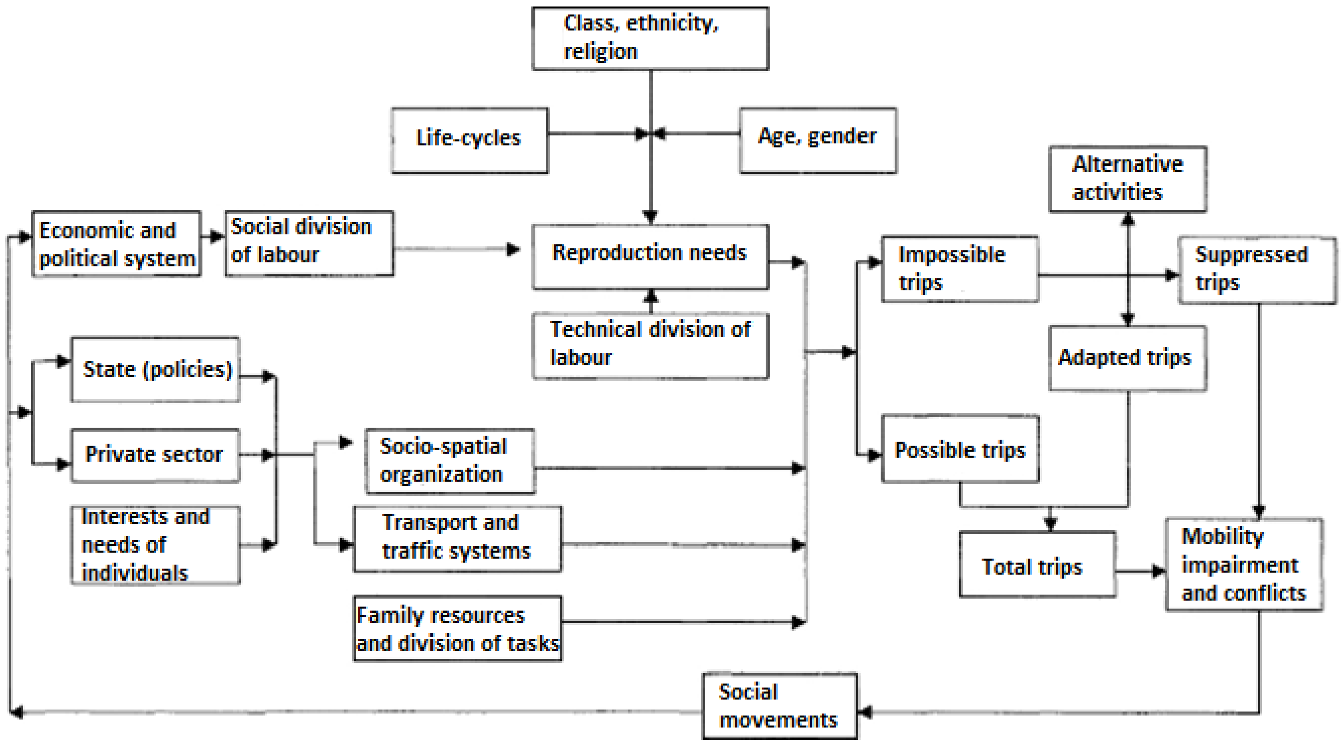


Figure 32: Comprehensive view of agents and factors influencing circulation (Vasconcellos E. A., 2014d)

In Figure 32, Vasconcellos (2014d) shows the complex relationship between the elements, which are constantly maintaining or changing socio-spatial conditions. Although Vasconcellos (2014d) does not mention directly the terms presented by Castells (2002) as the fields of the new urban sociology, he explores all four fields directly or indirectly.

It is possible to see that in Figure 32, the reproduction of needs represents the basis for the production of socio-spatial conditions presented by Castells (2009), which the spatial organisation of the city is a product of the conflict of interest and values of social classes, reflecting also on the transportation's physical representation on the built environment.

The social interests and needs, plus the public and private sectors, are direct actors on production of the social-spatial organisation and transport and traffic system. However, this logic does not guarantee the satisfaction of all individuals, groups or social classes regarding transportation, because the dominant interest tends to prevail (Harvey, 2008). According to the available socio-spatial organisation, transportation system and social characteristics (financial conditions and family division of task), the trips will be possible or impossible, leading the individual to search for alternatives or have the needs suppressed.

The suppressed needs that can be originated from dissatisfaction regarding the transportation or traffic system experience of individuals or groups can generate the representation of interests and values through the social movements. These social movements with the collective consumption goal, according to Castells (2009), have the intention of changing urban meaning, which according to Vasconcellos (2014d) can be changed through the change in urban policies towards attending their interests, values and needs.

Another aspect identified by Vasconcellos (2014d) is the relationship between urban mobility and the right to the city. Right to the city means the right for one to benefit from its profits and take part in the decision-making process of capital surplus investment (Harvey, 2003; 2008). It can be understood that a social class may or may not be exerting the right to the city, regarding transportation and traffic system, or more specifically, regarding urban mobility issues. Consequently, this can lead to inequality of socio-spatial conditions (Vasconcellos E. A., 2014a).

3.5. Energy, Environmental Impacts and Urban Transportation

As Rodrigue et al. (2013, pp. 1-41) affirms, energy is a significant element for the existence of the transportation system and it can be seen as a requirement to overcome geographical constraints (Greene, 2004). Furthermore, transport operators focus on two main elements, which are speed (returns in overcoming distance) and energy (cost in overcoming distance) (Rodrigue, Comtois, & Slack, 2013). From a physical perspective (Greene, 2004):

> *Physics defines work as the application of force over a distance, and energy as the ability to do work. To move any object from one place to another work must be done: force must be applied over distance to accelerate an object from rest, and it must be continually applied to overcome the frictional forces that oppose motion. Thus, transportation require the use of energy. Energy (p. 274).*

Coal was the main source of energy for transportation in the 19th and early 20th century. It powered ships and railroad steam engines. Petroleum has been growing as the main fuel of choice during the 20th until nowadays (Greene, 2004). Although there may be some discussion on whether fossil fuels will or will not become scarce, the argument in favour of the use of petroleum is still remains the abundant supplies, low cost, high energy density (in weight and volume) and ease of transport, handling and storage (Greene, 2004). However, transportation's reliance on petroleum brings problems regarding environmental impacts and energy security (Greene, 2004).

With respect to environmental issues, it is observed that the transportation sector is linked to impacts on this matter: climate change; air quality; noise; water quality; soil quality; biodiversity; and land take (Rodrigue, Comtois, & Slack, 2013). Below is a description of how transportation is related to these cited impacts (Rodrigue, Comtois, & Slack, 2013):

1. ***Climate Change***: The transport industry emits "several million tons of gases each year into the atmosphere" (Rodrigue, Comtois, & Slack, 2013, p. 258). Within these emissions, there is lead (Pb), carbon monoxide (CO), carbon dioxide (CO_2; not a pollutant), methane (CH_4), nitrogen oxides (NOx), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), silicon tetrafluoride (SiF_4), benzene and volatile components (BTX), heavy metals (zine, chrome, copper and cadmium) and particulate matter (ash, dust) (Rodrigue, Comtois, & Slack, 2013, p. 258). According to Rodrigue et al. (2013, p. 258), some of these gases can influence on the depletion of the stratospheric ozone (O_3), which protects the surface of the earth from high levels of ultraviolet radiation.
2. ***Air quality***: The transportation sector is a source of pollution – gas (CO, NO_2, SO_2 and NOx) and particulate matters' emissions can damage human health (Rodrigue, Comtois, & Slack, 2013, p. 258). These pollutants emitted by highway vehicles, marine engines, locomotives and aircrafts are associated with cancer, cardiovascular, respiratory and neurological diseases; and other impacts on human health, such as skin irritation, eyes inflammation, blood clotting and allergies (Rodrigue, Comtois, & Slack, 2013, p. 258). These pollutants can also damage agricultural crop yields and cause forests to decline (Rodrigue, Comtois, & Slack, 2013, p. 258).
3. ***Noise***: According to Rodrigue et al. (2013, p. 258) a "long term exposure to noise levels above 75dB seriously hampers hearing and affects human physical and psychological wellbeing" (p. 258). The noise generated from the transport sector, through the movement of vehicles, operation of port, airport and rail yard are able to affect human health (Rodrigue, Comtois, & Slack, 2013, p. 258).

4. ***Water quality***: The pollutants emitted from the transportation sector, from the industry, vehicles or terminals, are discarded on the environment, which can contaminate rivers, lake, wetlands and oceans (Rodrigue, Comtois, & Slack, 2013, p. 259). This contamination of water can also affect human health and affect the ecosystem (Rodrigue, Comtois, & Slack, 2013, p. 259).
5. ***Soil quality***: The impact of transportation on soil is characterised by (Rodrigue, Comtois, & Slack, 2013, p. 259) soil erosion and contamination. The transport sector generates this impact, e.g. through removal of earth surface for the construction of highways, ports and terminals; and through the spills of fuel and oil from vehicles (Rodrigue, Comtois, & Slack, 2013, p. 259).
6. ***Biodiversity***: The growth of transportation infrastructure and urbanisation has been responsible for deforestation and change in the biodiversity, by introduction of new species, different from those that grew originally in a certain area (Rodrigue, Comtois, & Slack, 2013, p. 259). The process of deforestation restricts the growth of plants and the range of animals' accessibility into their natural habitat, even causing extinction or reduction of a species in determined areas (Rodrigue, Comtois, & Slack, 2013, p. 259).
7. ***Land use***: This impact is related to the change in the landscape. The building of ports, terminals, bridges, highways and elevated trains can impact the perspective of the landscape, generating impact on social and economic aspects (Rodrigue, Comtois, & Slack, 2013, p. 260). These changes on the landscape can consequently affect the urban quality of life, through the creation of physical barriers, increasing noise, generation of odours, reducing urban aesthetics and affecting the built heritage (Rodrigue, Comtois, & Slack, 2013, p. 260).

It is possible to observe that the emission of gas and pollutants are within the main causes of impact from the transport sector, when regarding climate change, soil and air contamination. Figure 33 shows recent data and expected values of CO_2 (main GHG) emissions in different sectors, until 2030. It is observed that the transport sector comes right after the power generation and energy sector with respect to CO_2 emissions. Generally, it is expected that CO_2 emissions tend to grow in all sectors of society.

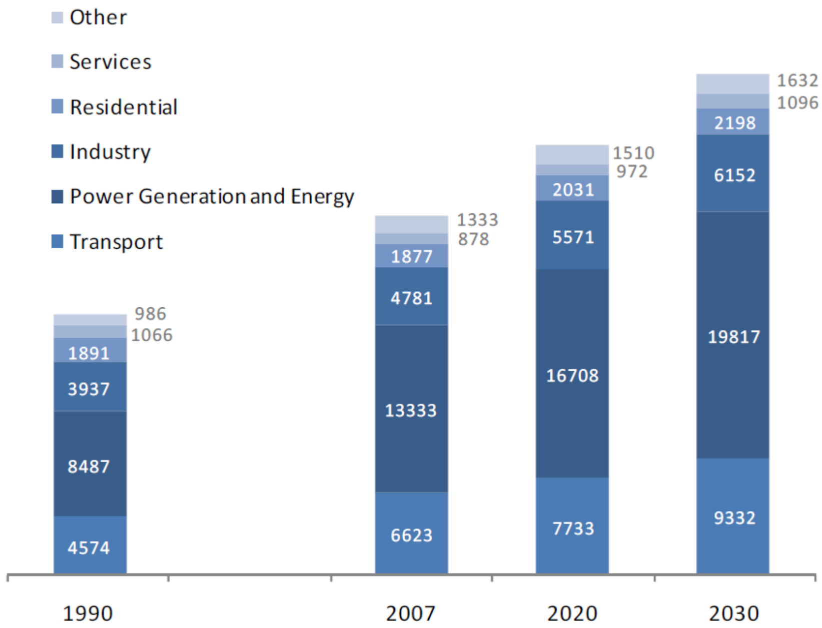


Figure 33: Projected world energy-related CO_2 emissions (Mt) (OECD/ITF, 2010)

In Figure 34, there is the information (of 2010) of the transport energy used by source and by mode. Based on this figure, it is possible to observe that fossil fuels are dominant in the transportation sector. Furthermore, when observing the transport energy use by type, road transportation is seen as dominant, more specifically, Light Duty Vehicles (LDV) (light trucks, light commercial vehicles and minibuses), trucks and bus, summing a consumption of 73% of total energy use in the transportation sector, where the LDV is the highest with 52%.

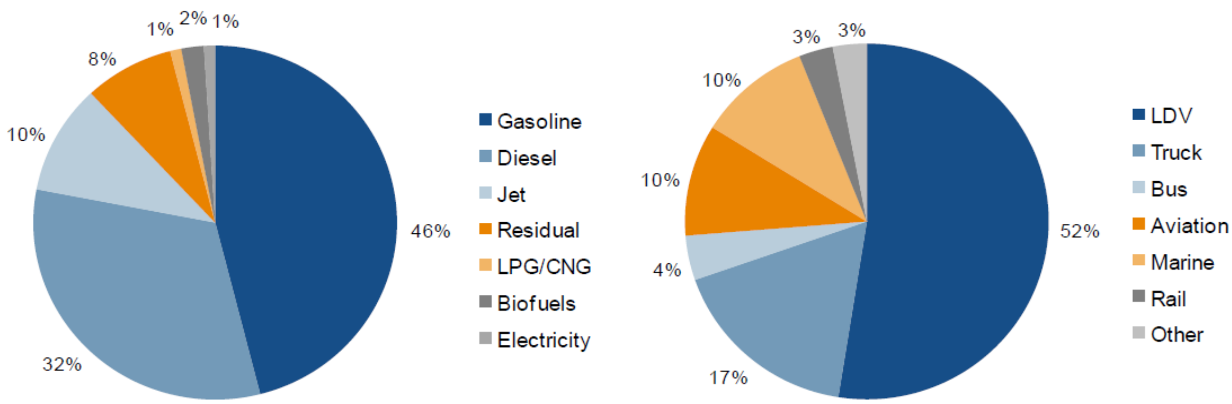


Figure 34: 2010 transport energy by source and by mode (total ~2,200 Mtoe) (World Energy Council, 2011)

According to Rodrigue et al. (2013, p. 265), "the private car is the dominant mode, but has poor energetic performance, although this performance has seen substantial improvement since the 1970s". Studies have shown that there is close relationship between car ownership, rising income and distance travelled by vehicle (Rodrigue, Comtois, & Slack, 2013). When observed at a global scale, urban transportation has been increasing towards private cars and fossil-fuelled buses. Thus, the question remains whether this mobility logic can resist an increase in the price of oil or even a depletion of it.

At the European scale, the European Commission has established that by 2050 conventionally-fuelled cars shall be forbidden in urban areas. Furthermore, it is expected a 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport (European Commission, 2011). These goals address the interest of the European Union to shift towards electric vehicles and electric-based public transportation, in order to be less dependent on fossil fuels.

In contradiction with the sustainable approach, it is possible to observe in Figure 35, that the global fuel consumption of cars tend to increase between 2010 and 2050 (World Energy Council, 2011). Furthermore, the World Energy Council (2011) adds that the expected prospect is that:

> *The world's car fleet will still depend heavily on gasoline and diesel, which will still constitute about 80% of the fuel mix in 2050. Biofuels will constitute around 12%, while CNG will provide about 5% (2011, p. 53).*

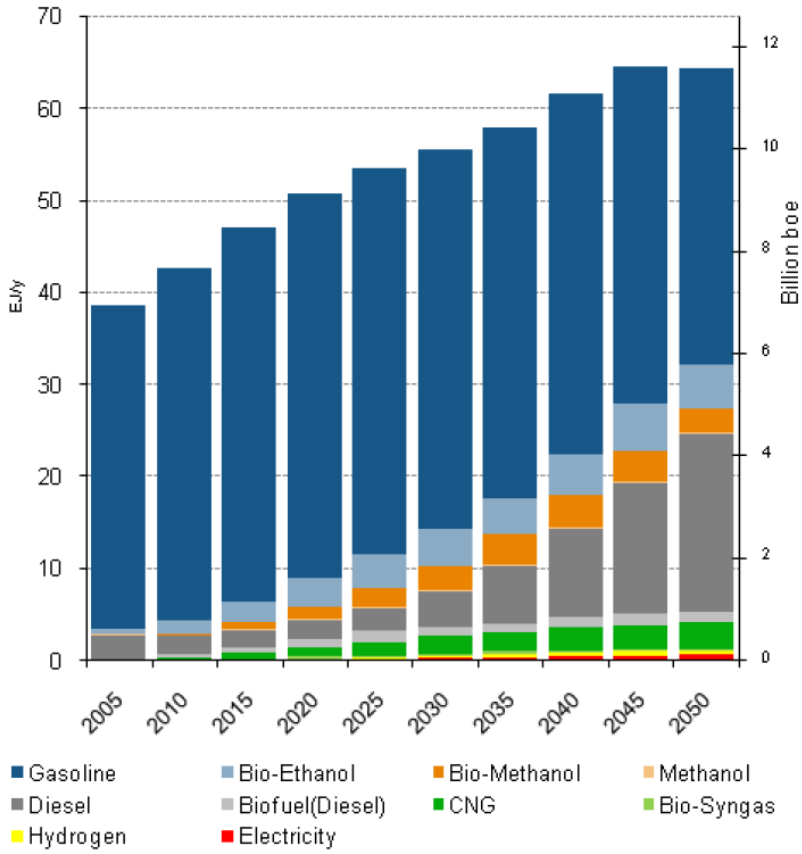


Figure 35: Fuels for LDV cars – Global Demand between 2010 and 2050 (World Energy Council, 2011)

According to Gilbert and Perl (2008), there are two main constraints regarding oil extraction that can influence the availability of this resource. The first can be pointed out through Figure 36, which presents that the rate of consumption has not been following the rate of oil reserve discoveries since the 1960s.

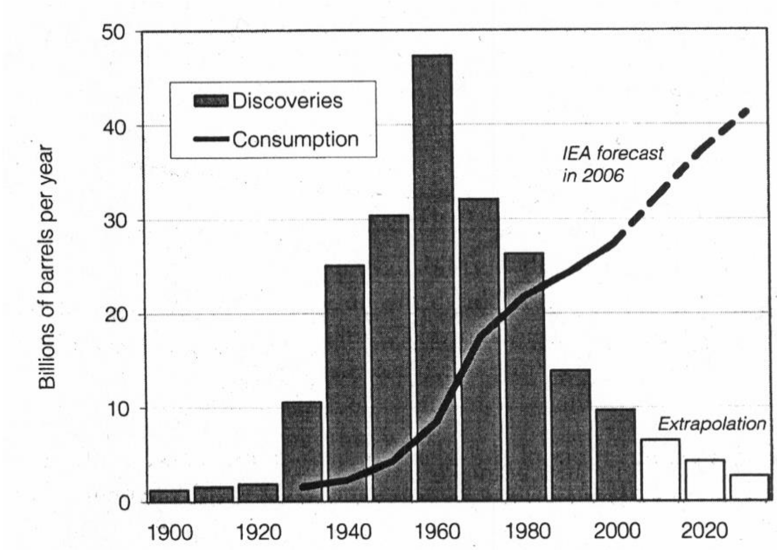


Figure 36: Actual and projected oil discovery and consumption, 1900–2030 (Gilbert & Perl, 2008, p. 124)

The second factor can be related to the understanding of what is conventional oil and non-conventional oil (Gilbert & Perl, 2008). The first one is characterised as easy to extract and process, available in accessible locations, which is often under pressure (Gilbert & Perl, 2008). The conventional oil composes around 95% of all oil that has been extracted until nowadays (Gilbert & Perl, 2008). The non-conventional oil "is in remote places or requires much mining and processing, or both" (Gilbert & Perl, 2008, p. 126). To extract and process non-conventional oil can be much more expensive than conventional oil (Gilbert & Perl, 2008).

Although there are many discussions on peak oil, whether it is something that has already happened or not, there is a common notion within organisations, scholars and governments that the peak oil will happen any time in this current century (Gilbert & Perl, 2008, p. 129; Hopkins, 2008; Heinberg, 2003). Even the U.S government sponsored a famous report on this topic known as the *Hirsh Report* (Hirsch, Bezdek, & Wendling, 2005). In this report, some dates regarding the occurrence of peak oil was reviewed (Table 7). However, these predictions can be seen from two perspectives: doubtful or approximated.

Table 7: Predictions of World Oil Production Peaking (Hirsch, Bezdek, & Wendling, 2005)

Projected Date	**Source of Projection**
2006-2007	Bakhitari
2007-2009	Simmons
After 2007	Skrebowski
Before 2009	Deffeyes
Before 2010	Goodstein
Around 2010	Campbell
After 2010	World Energy Council
2010-2020	Laherrere
2016	EIA (Nominal)
After 2020	CERA
2025 or later	Shell
No visible Peak	Lynch

The doubtful perspective is related to the uncertainties about the extractable amount of oil, mainly because there is still classified information within governments and companies regarding these issues (Hirsch, Bezdek, & Wendling, 2005; Hopkins, 2008). The approximated perspective has to do with the understanding that production may not follow the same pattern as the demand, because oil is a limited resource and naturally, its availability in the environment is less (Figure 36), if extraction rate keeps growing (Figure 37). Either way, it is undeniable that at some point, the second perspective will be reached.

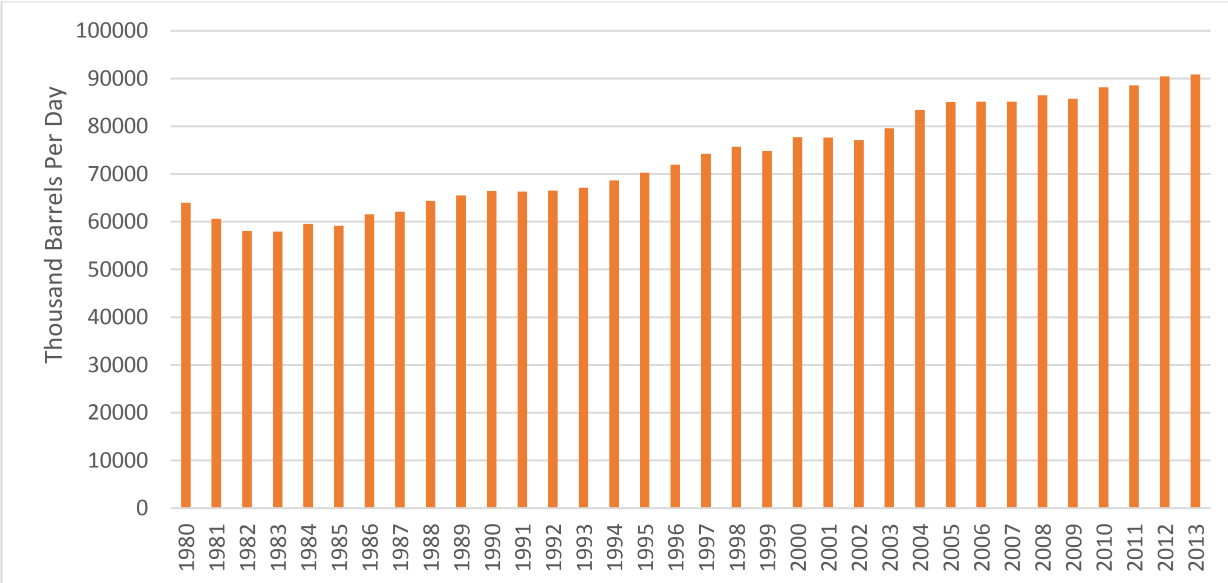


Figure 37: Total Oil Supply (Thousand Barrels Per Day) (IEA, 2015)

When dealing with the crude oil price, one of the most volatile prices within other commodities is considered (Regnier, 2007). According to Regnier (2007), "crude oil, refined petroleum and natural gas prices are more volatile than 95% of products sold by domestic producers" (p. 405) and related to crude commodities, it is more volatile than 65% of the other products.

Although economists may argue that the oil price volatility is not necessarily bad, its fluctuation can be harmful for household consumers (Regnier, 2007). There are countries that maintain strategic petroleum reserves in case there is a supply disruption, whether it is for natural disaster or anthropogenic reasons (Regnier, 2007).

Sipe and Dodson (2013) points out that the growth in the volatility of petroleum price, from 2004 onwards, had affected fuel costs in most nations. In addition to this, they also argue that the fuel price volatility in combination with the housings marked raises important issues regarding the urban system. Sipe and Dodson (2013) add that:

> *Housing systems, which have been spatially structured on the basis of relatively cheap transport fuel, face a process of difficult adjustment in a volatile and likely higher fuel-cost environment that will intersect with global economic weakness, especially in credit markets* (2013)

“The history of modern urbanization shows that transportation has been a crucial means for solving housing problems” (Sipe & Dodson, 2013), so, there is still sparse literature in urban social science (e.g. urban sociology and transport geography) that regards the dynamics of energy and financial stress on urban socioeconomic structures and patterns (Sipe & Dodson, 2013).

It is understood that there can be many reasons, which can affect growth and volatility of oil price, and these reasons are as follows (Sipe & Dodson, 2013): rapid global economic growth; production constraints and disruption; geopolitical tensions; and long-term fears about resource sustainability.

Faced with the instability in oil prices and its high levels of use as a source of energy for transportation, what are the available options? Gilbert and Perl (2008) present alternatives resources to oil products, which they found in the literature: natural gas; coal; biofuels; hydrogen; and electricity.

Opting for natural gas can be seen as a positive change in the transportation sector, the fact that it is willing to exchange one fossil fuel for another (Gilbert & Perl, 2008). According to Gilbert and Perl (2008), natural gas can be carried compressed or in liquid form, and approximately 90% of diesel fuel can be replaced by natural gas. In addition to this, it burns more cleanly than petrol or diesel fuel and it can be cheaper if it is less heavily taxed (Gilbert & Perl, 2008). However, the limitations of natural gas show itself on the weight and size of fuel tank issues.

The second proposed alternative is the use of coal, also a fossil fuel. Gilbert and Perl (2008) present three ways in which coal can be used in the transportation sector: (1) as solid fuel for external combustion engines, to provide traction to steam locomotives and ships; (2) as liquid fuel through the Fischer-Tropsch process; and (3) coal to electricity. According to MIT (Massachusetts Institute of Technology), it is predicted that between 2000 and 2050, the consumption of coal in terms of energy could rise to 48% (Gilbert & Perl, 2008). Furthermore, IEA suggest that at the current rate of consumption, coal has a longer duration time, when compared with natural gas and oil (Gilbert & Perl, 2008).

Biofuels are the third proposed alternative fuel. There are three notable types of biofuels (Gilbert & Perl, 2008): ethanol, biodiesel and biogas. Ethanol is made from fermentation and distillation of sugars derived from corn or sugarcane. Biodiesel is made from vegetable oils, through the process of transesterification. Biogas is “made from anaerobic digestion of waste plant material” (Gilbert & Perl, 2008, p. 140). Although, biofuels itself are cleaner than fossil fuels, they “require substantial amounts of petroleum derived fertilizer and pesticide” (Gilbert & Perl, 2008, p. 140), consequently contributing to the emission of CO_2 in the atmosphere. The limitations of ethanol are currently related to the amount of land needed to produce energy (Gilbert & Perl, 2008). There is a way to reduce the use of land through cellulosic ethanol, “produced by enzymatic processing of the presently unused fibrous components of plant maize and other plant sources” (Gilbert & Perl, 2008, p. 142), however, this process is not commercially available.

In the case of biodiesel, it is “usually blended with petroleum diesel” (Gilbert & Perl, 2008, p. 142), but it can be used without blending it. Biogas is mixed with natural gas and it can be used to spark ignition (Gilbert & Perl, 2008).

Another alternative for the transportation sector is hydrogen, with hydrogen fuel cells. The constraints of this source of energy are related to costs and reliability (Gilbert & Perl, 2008). The hydrogen fuel cells still present a certain inefficiency, because hydrogen is produced using renewable resources (Gilbert & Perl, 2008). Hydrogen energy is produced by producing electricity to power electrolytic production of hydrogen that would be used to produce electricity in fuel cells, in other words, transiting “from electricity to hydrogen and then back to electricity” (Gilbert & Perl, 2008, p. 146). This means there is an energy loss between 57% and 80% (Gilbert & Perl, 2008). According to Gilbert and Perl (Gilbert & Perl, 2008):

> *The main reason the hydrogen fuel cell vision had been popular is that it provides for vehicles that are similar to those of today in two important features: quick refueling and the ability to carry enough fuel for a range of several hundred kilometers (p. 147).*

The last suggested alternative is electricity. Electric vehicles are known to be quiet, energy-efficient, requiring little maintenance, having good acceleration at low speed and emitting essentially no pollution (Gilbert & Perl, 2008). There are three types of electric vehicles (Gilbert & Perl, 2008, p. 148): (1) battery-electric vehicles; (2) hybrid vehicle; and (3) Grid-Connected Vehicles (GCVs).

In the first type, electricity is generated and then stored on board, and subsequently delivered to the motor. In the second type, the electricity is generated on board and works together with other fuels (e.g. gasoline or diesel). In the third type, the electricity generated is sent directly to the motor by wire or rail.

Considering these issues, it is understood that the energy used in the transportation sectors has much to do with costs and benefits. Environmental and social concerns are still being slowly introduced into this sector. As this thesis aims to understand the vulnerability of urban mobility faced with fossil fuel dependency, focussing into the social perspective, the concept of energy security is discussed, in order to contribute to the framework of resilient mobility, which is drawn in the following section.

3.5.1. Energy Security: Concept Review and links with the transportation sector

> *Twenty-first century access to energy sources depends on a complex system of global markets, vast cross-border infrastructure network, a small group of primary energy suppliers, and interdependencies with financial markets and technology (Chester, 2010, p. 887)*

According to Chester (2010), the concept of energy security arose in the government's interest around the world in this context. More specifically, the energy security concept was strengthened after World War II, mainly because of the growing dominance of fossil fuels, the liberalisation of energy markets, the development of nuclear energy, the energy demand of developing countries, political instability and large-scale natural events (Chester, 2010).

The energy security concept is considered as a broad concept, because at a basis line, most scholars would agree that it is a concept that deals with risks, however "the number of threats that are caused by or have an impact on the energy supply chain is huge" (Winzer, 2012, p. 37). This fact leads to a number of ways to deal with energy security, depending on the risk source, chosen impact measures and the minimum threshold value to be considered as a threat to energy security (Winzer, 2012).

In order to understand all types of approaches, Winzer (2012) developed a framework, which shows the dimensions of energy security, presented in Figure 38. Figure 38 presents three groups of risk sources (technical risk, human risk and natural risk), which presents the types of risk that can be considered in a study. Furthermore, it also presents the scope of impact measure, divided into four groups (continuity of commodity supply, continuity of service supply, continuity of economy and environment and society), which describes ways to measure energy security.

Beyond these two factors, there are six more factors within the severity filter group, which Winzer (2012) considers to be the subjective aspects that distinguish the secure and insecure levels of continuity.

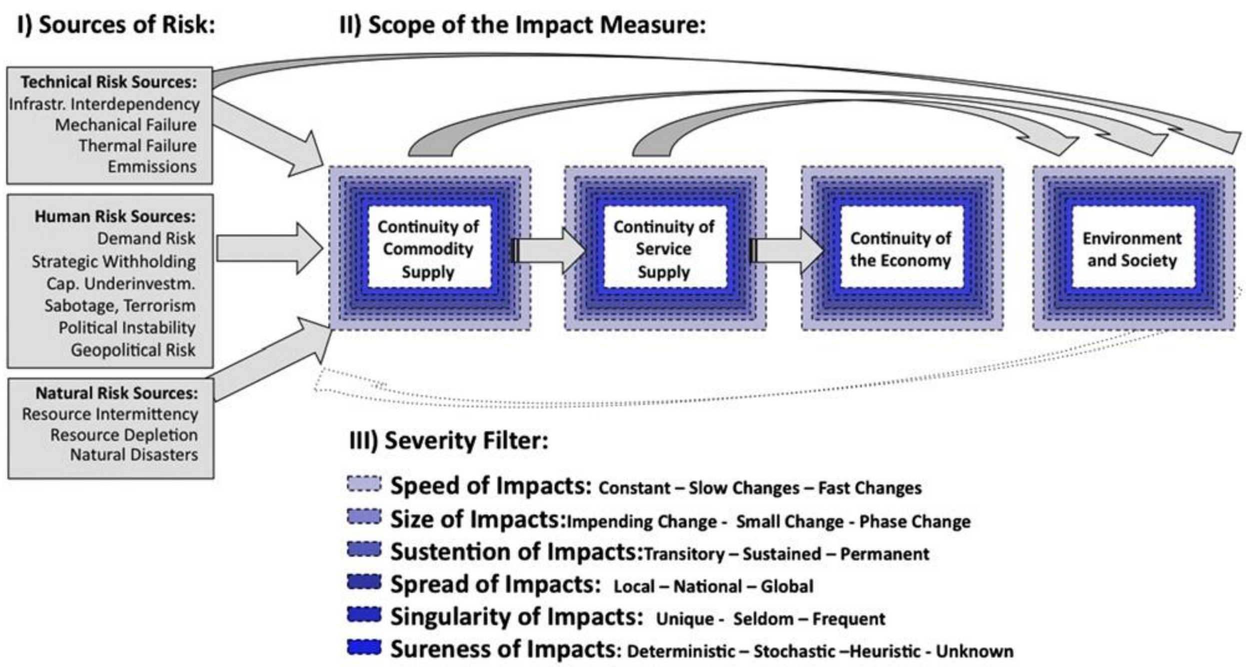


Figure 38: Dimensions of energy security (Winzer, 2012)

To understand the framework more precisely, each of the elements that Winzer (2012) includes in his framework is reviewed. Firstly, regarding the sources of risk (I), the technical risks are related to failure of infrastructural components, such as transmission lines' power plants or transformers, whose source of problem can be mechanical failure or human error (Winzer, 2012). The human risk sources are related to demand fluctuation, strategic withholding of supplies, underinvestment capacity, sabotage, terrorism, political instability and geopolitical risks (e.g. wars and export embargos) (Winzer, 2012). Lastly, the natural risk sources are related to stochastic intermission of renewable energy supplies, the depletion of fossil fuel stocks and natural disasters (Winzer, 2012).

Regarding the scope of impact measures, usually, the common ground between the different measures is the "idea of avoiding sudden changes in the availability of supplies relative to demand" (Winzer, 2012, p. 37). The detail added by Winzer (2012) is the possibility to measure the continuity of the supply in several stages. It can be measured in terms of continuity of the commodities' supply, which means the continuity of price and availability of different energy commodities, such as oil, gas, coal and electricity (Winzer, 2012). The next measure is the continuity of service supplies, which involves the continuity of price and availability of energy services (e.g. heating, lighting, communication or transport) (Winzer, 2012). The repercussions of these discontinuities can be further measured in terms of economic continuity, based on the continuity of the productivity and/or continuity of the welfare levels enjoyed by the citizens (Winzer, 2012). The last measure presented by Winzer (2012) regards human safety and environmental sustainability, which involves, for instance, the impact of nuclear proliferation and water pollution. Winzer (2012) adds:

> *Because some of the commodities and services may be substitutes, a discontinuity at an earlier stage does not have to lead to a discontinuity at a later stage of the transformation process (p. 38)*

In the review of Winzer (2012), subjective severity filters are also identified, which are related to the subset of risk sources and impact measures. The severity filters are related to the severity of an impact threat with the increase in speed, size, sustention, singularity and sureness of the threat. The description and levels of each severity filter is described in Table 8.

Table 8: Severity filters description

Severity filters	Description	Levels
Speed of threat impact	Time-scale on which the impact of risk materialises	-Constant scarcity (e.g. renewable potential of a country); -Slow stresses (e.g. depletion of fossil fuels, accumulation of GHG or growing demand); -Fast shocks (e.g. political disruption, technical failure or intermittency)
Size of threat impact	Magnitude of changes in scarcity within the affected area	-Impeding changes (e.g. reduced reserve margin) -Small change (e.g. price volatility or marginal rises of global temperature) -Phase change (e.g. physical delivery disruption or global warming in a higher level)
Sustention of threat impact	Duration during which the impact of a threat persists	-Transitory (e.g. small interruptions and short term price volatility) -Sustained (e.g. slower or fast threats that exceed certain size and last for a considerable amount of time) -Permanent (e.g. fossil fuel depletion)
Spread of threat impact	Size of the largest geographical unit that is simultaneously affected	-Local level (e.g. individual household, city, or region within a country) -National level -Global level
Singularity of threat impact	Frequency of recurrence	-Unique (e.g. fuel depletion, anthropogenic climate change and nuclear wars) -Infrequent (e.g. political disruption and natural catastrophes) -Frequent (e.g. alteration of wind-speed or some technical faults)
Sureness of threat	Levels of uncertainty about the threat	-Predicted (e.g. fossil fuels depletion) -Probabilistic (e.g. resource intermittency or technical failure) -Heuristic (e.g. political disruption or terrorist attack) -Unknown

Source: adapted from Winzer (2012)

The notion of energy security given by Winzer (2012) brings an aggregated review of recent works in energy security, through his framework and definitions. The next step of this research is to understand how energy security and the other elements reviewed previously, correlates with urban mobility towards the definition of urban mobility, establishing the social structure in the centre of the system.

3.6. Urban Mobility Framework: The Social Structure as Centre of the System

This section's objective is to gather what have been reviewed in the literature, within transport geography, economic geography, urban sociology, transport sociology, energy and environmental issues and build a framework of urban mobility. Figure 39 shows the proposed theoretical framework on the issue of urban mobility, locating the social structure at the centre of the system.

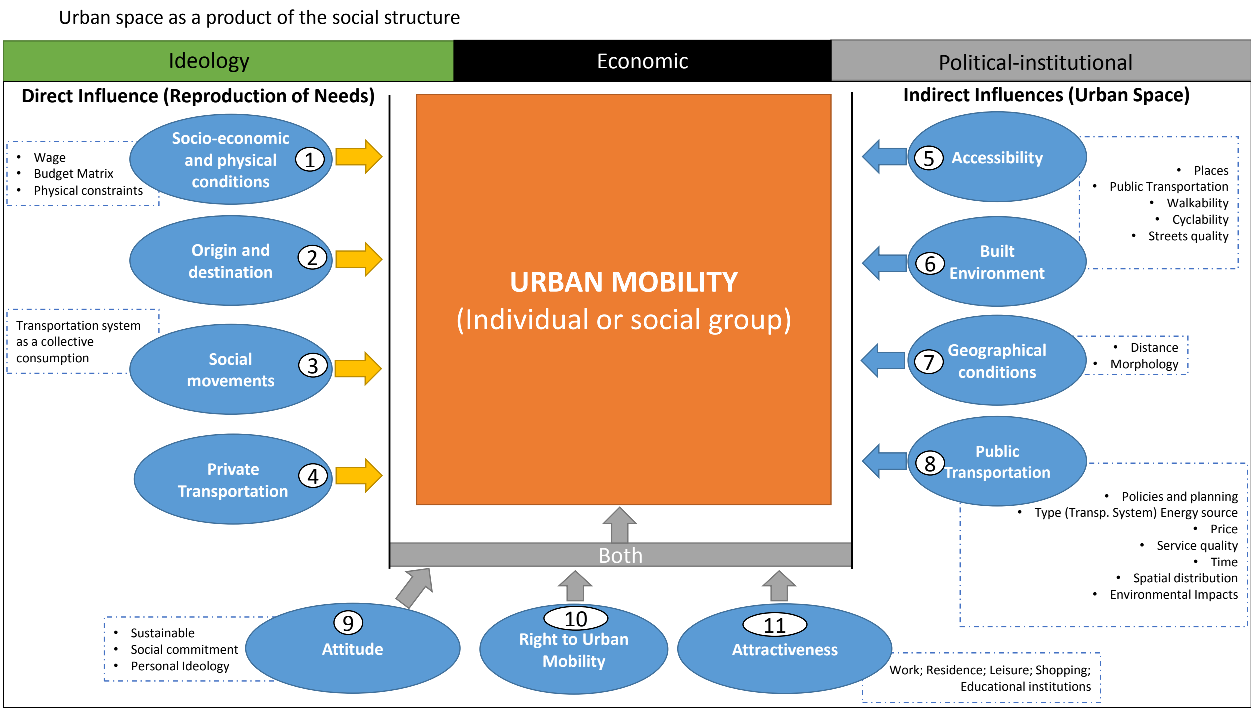


Figure 39: Urban Mobility Framework

The proposed framework is based on the understanding of the urban space as an ecological unit, based on the School of Chicago, however with the social element as the central issue of the system, based on Castells (2009). Furthermore, the urban space is seen as a product of social interests and contradictions, which are spatially represented by three elements (Castells, 2009): ideology, economic and political institutional.

At the centre of the framework (Figure 39) there is urban mobility (of an individual or social group), which is related to 11 elements. Based on the definitions of direct and indirect demand of transportation by Rodrigue et al. (2013, pp. 1-41), the elements were defined in three types of influence over urban mobility: direct, indirect and both. These three types of influence are defined as follows:

1. ***Direct***: An influence that comes from the characteristics of an individual or social group;
2. ***Indirect***: An influence that comes from the characteristics of the space and services built by other individuals or social group (those who use are not necessarily the same who plan and implement);
3. ***Both***: It represents the possibility of the element to have a direct and/or indirect influence. In other words, it can be at both the same time, but not necessarily, depending on the social structure and ideology.

The logic of influences shown in Figure 39 and Figure 40 is not only based on the transportation systems' direct and indirect demand (Rodrigue, Comtois, & Slack, 2013), but also on the logic of transport sociology presented by Vasconcellos (2014d), who believes that one of the factors of mobility is the reproduction of needs. The reproduction of needs is based on social characteristics, such as class, ethnicity, religion, gender and age (Vasconcellos E. A., 2014d). In addition to this notion, there is the influence of the spatial characteristics (indirect influence), in a sense of whether these characteristics can reach the expectation of needs (direct influence).

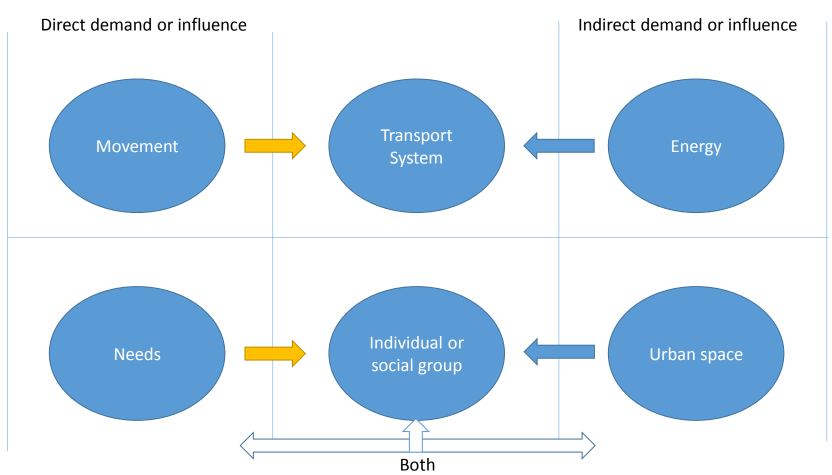


Figure 40: Framework of influences on transportation system and social group (or individual)

Although in Figure 40, visually the indirect and direct may seem separated, there can be elements inserted in both sides, which is the case of the element right to urban mobility (element 10). The case of element 10 is based on the conceptualisation of Harvey (2008) on the right to the city, in which it can either dispossess people from the liberty of choice or people can participate in the production process (in terms of decision) and benefit from the surplus. The right to urban mobility is considered both, because of the same reasons that if one considers that policies and planning process regarding transportation can be driven by different actors, but in some cases, those who use the system are not included in the decision process. To understand the other elements, Table 9 shows a description of all elements identified in the literature review, which can influence urban mobility.

Table 9: Description of elements influencing urban mobility (based on Figure 39)

Elements	Type of influence	Description	Main References
1	Direct	This regards to information such as class, ethnicity, religion, gender, age and social and technical division of labour. There are subsets of information that can be present within these factors.	(Vasconcellos E. A., 2014a)
2	Direct	The trip matrix of a group or individual – where people are going (destination) and where they are coming from (origin). Furthermore, it is related to the available options of mobility in order to fulfil a trip.	(Vasconcellos E. A., 2014a)
3	Direct	This is related to social movements with the collective consumption goal, which are interested in changing policies that improve the urban mobility, based on their interest, values and needs, consequently allowing a change in urban meaning.	(Castells, 1983)
4	Direct	This regards to the ownership of private transportation and frequency of use. Within this element, there are other subjective factors related to the reason why one prefers private to public transportation.	(Vasconcellos E. A., 2014a)
5	Indirect	The number of opportunities for one to reach a destination, available within a specific distance or travel time.	(Hanson, 2004)
6	Indirect	This is related to the available infrastructure for citizens, considering transportation system, land use distribution, cycleways, sidewalks and other factors related to the built environment that can constrain mobility.	(Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009)
7	Indirect	This regards to distance and morphology of the land, between origin and destination.	(Rodrigue, Comtois, & Slack, 2013)
8	Indirect	This element is related to the available transportation system, regarding also specific modes and energy source used. In addition to this, subjective reasons, such as in number 8 can also be considered.	(Vasconcellos E. A., 2014a)
9	Both	Understanding that there can be the ideology of a social class, this element is related to the ideology of an individual or a group, regarding, specifically, to the attitude and to how this aspect can influence the willingness to adapt. For example, sustainable or social commitment, or another personal ideology.	(Castells, 2009)
10	Both	This regards to the right to participate in planning and policymaking processes and to benefit from mobility options (directly or indirectly).	(Harvey, 2008)
11	Both	This is related to the reason why an individual or a group exerts the movement activity, especially where one is able to fulfil the needs.	(Vasconcellos E. A., 2014a)

This section gives an overview of urban mobility, based on the elements that can influence the mobility of individuals and social groups within an urban area. The framework contributes to a sociological perspective on urban mobility, by joining elements from the literature review, under a scientific process of analysis.

Under this understanding of urban mobility, the next section focusses on building a framework and concept of resilience of urban mobility, faced with fossil fuel dependency.

3.7. The Resilience of Urban Mobility Faced with Fossil Fuel Dependency: Framework and Concept

This section focusses on building the resilience of urban mobility framework and concept, based on the urban mobility framework, the resilience concept and the fossil fuel dependency context. To get a precise understanding of the resilience concept, this section provides a brief review of the notion of the concept of resilience, before building the intended framework.

3.7.1. Resilience Concept Review

As the intention of this research is not to use the term “resilience” from a subjective perspective, before building the resilient mobility concept, the meaning of resilience is reviewed. The Oxford Dictionary offers two definitions of resilience, which are as follows:

- The ability of a substance or object to spring back into shape; elasticity;
- The capacity to recover quickly from difficulties; toughness.

From the dictionary’s point of view, there are two definitions, which are presented separately. The first one is elasticity, which is related to substance and objects. The second is toughness, which is different from the first definition, as there is a more subjective approach of the “object”. It does not specify the toughness of what element it is defining. Therefore, the term “resilience” is intentionally left with a definition that allows one to apply it to any issue.

According to Béné (2014), the usage of the term resilience evolved during the 20th century from an ordinary term, when it was referred simply as the capacity to recover quickly from difficulties, to sophisticated scientific concepts defined according to the field of work that uses it, as is shown in Figure 41.

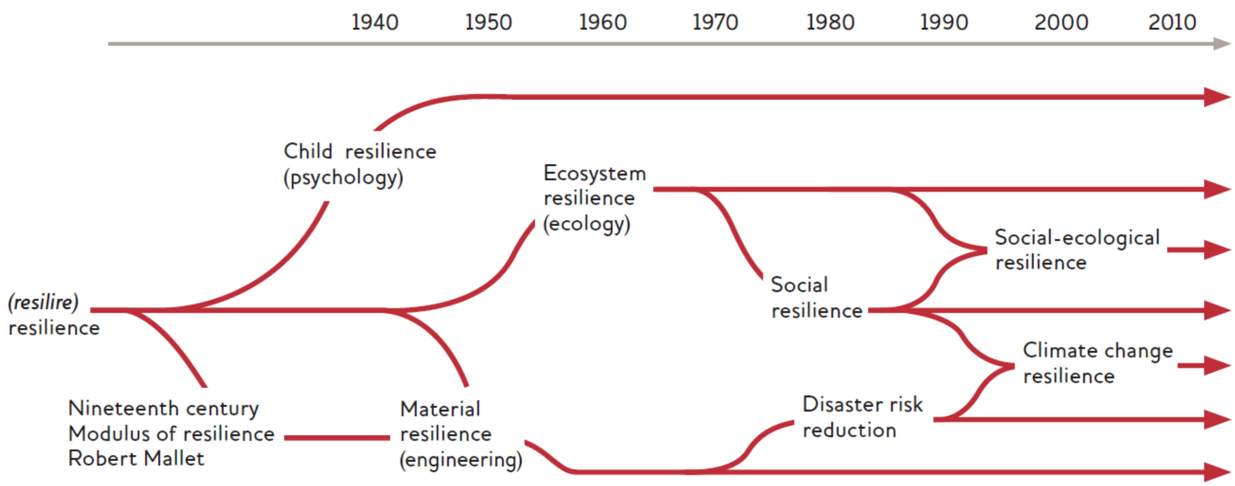


Figure 41: Evolutionary path of the concept of resilience and emergence of the different schools of thoughts and their lineages (Béné, Gupte, Mehta, & Tanner, 2014)

Collier et al. (2013) also identified that different emphasis can be given to resilience studies. They point out that it can be used to describe the response to environmental disturbance and it can focus on the vulnerability of a system towards an external change, or even focus on the capacity of adaptation within a system, facing changes.

It is observed that the resilience concept can be applied in different research fields, because of its adaptable approaches, which can be addressed in terms of vulnerability, capacity of adaptation, resistance, elasticity or toughness. Even though these words can mean almost the same, when applied to a certain study it can have different meanings, if attached to other terms, e.g. material resilience, environmental resilience, social resilience, psychological resilience, political resilience, etc.

According to Folke et al. (2010), the term “resilience” was initially introduced by Holling (1973), who focussed on resilience as a concept related to the capacity of ecosystems to persist in the original state, when subjected to changes. Folke et al. (2010) presents the concept of social-ecological resilience to be used in studies, in order to understand the adaptability and transformability of a social-ecological system.

Social-ecological resilience deals with society and nature as an interdependent system (Folke, et al., 2010). According to the argument that social change is essential for the socio-ecological resilience, Folke (2010) suggests incorporating adaptability and transformability as the key features of this resilience approach, besides persistence, which is usually included:

> *Adaptability captures the capacity of the socio-ecological system to learn, combine experience and knowledge, adjust its response to changing external drivers and internal processes, and continue developing within the current stability domain or basin of attraction (Folke, et al., 2010, p. 2)*

Transformability is related to the capacity of system “to create fundamentally new system when ecological, economic or social structures make the existing system untenable” (Folke, et al., 2010, p. 4).

In addition to this, Folke et al. (2010) affirms that these notions add to the resilience of the social-ecological system, because it broadens resilience studies towards including social actors, in order to understand their roles in changing and vulnerabilities in facing changes. From this perspective:

> *Resilience is the tendency of a socio-ecological system subject to change to remain within a stability, domain, continually changing and adapting yet remaining within critical thresholds. Adaptability is the capacity of a socio-ecological system to adjust its responses to changing external drivers and internal processes and thereby allow for development within the current stability domain, along the current trajectory. Transformability is the capacity to create new stability domains for development, a new stability landscape, and cross thresholds into a new development trajectory (Folke, et al., 2010, p. 7).*

Based on Folke (2010), Figure 42 was drawn to represent a general view of the social-ecological resilience. This figure shows that there can be different types of threats, which can influence the social-ecological system that can vary from economic, social, cultural, environmental or political origin. The three factors within this system that may or not be in practice are shown below:

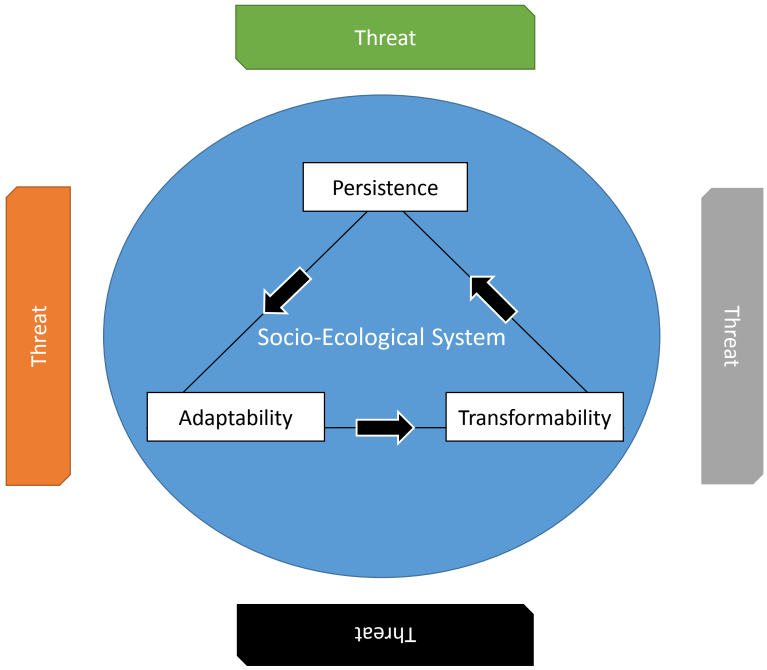


Figure 42: General framework of the social-ecological resilience (Source: adapted from Folke et al. (2010))

Firstly, there is the persistence factor, which can be interpreted as the characteristic of this system that can reflect the level of vulnerability, toughness or elasticity. In other words, it can be interpreted as the potential of the system to maintain current conditions of functionality, when exposed to an internal or external stress.

Secondly, there is the factor of adaptability, which is not only linked to the potential of maintaining the system in the stability domain, but also learning, through the combination of experience, knowledge and new opportunities to avoid future instability.

Thirdly, there is the factor of transformability, which is related to the creation of new stability domains, which can avoid threats that could jeopardise a system in a past stability domain. These three factors compose of the resilient concept, which is considered in this research.

3.7.2. Framework and Concept: Resilience of Urban Mobility Faced with Fossil Fuel Dependency

This section presents the result of the construction of the theoretical background through chapter 3. There are two main objects of study in this thesis: urban mobility and fossil fuels (energy). The intention of this section is two join these objects and relate them to the resilience concept.

As this thesis views the urban space as an ecosystem, where the social elements are at the centre of it, it is understandable that urban mobility can be seen as a one of the social systems within that urban space.

Based on the resilience concept drawn in the previous section, the conditions of urban mobility can be jeopardised by threats, which can be based on direct and indirect influences drawn in Figure 39. Within the logic of the determined resilience concept for this thesis, the resilience of urban mobility is based firstly on the persistence factor and it can aggregate the adaptability and transformability factors as well. Therefore, the concept of resilience of urban mobility is the ability of the urban mobility to maintain current functionality, considering the possibility to maintain mobility pattern, adapt mobility patterns, or by creating new mobility opportunities. Besides the maintenance of the functionality of urban mobility, resilience involves maintaining social-economic conditions, when exposed to threats from direct and indirect elements, within the urban mobility framework, presented in Figure 39.

The resilience of urban mobility is constituted by the ability to recover the functionality of the urban mobility to a previous stable domain (before the threat). It can involve a gathering of experience and knowledge towards avoiding future threats (adaptability) and develop in way, such that a new stable domain is created, in order to avoid being vulnerable to past threats.

This research poses the fossil fuels as a threat to urban mobility. However, fossil fuels are also a matter of energy security. From this perspective, the threat of fossil fuels can come from different sources of risk, generating impact over different scopes and containing different levels of impact (severity filters), as well as the urban mobility that can have levels of impact based on its own characteristics of the direct influences.

Figure 43 represents the framework of the resilience of urban mobility as a product built under the interpretation of the literature review in different fields along this thesis.

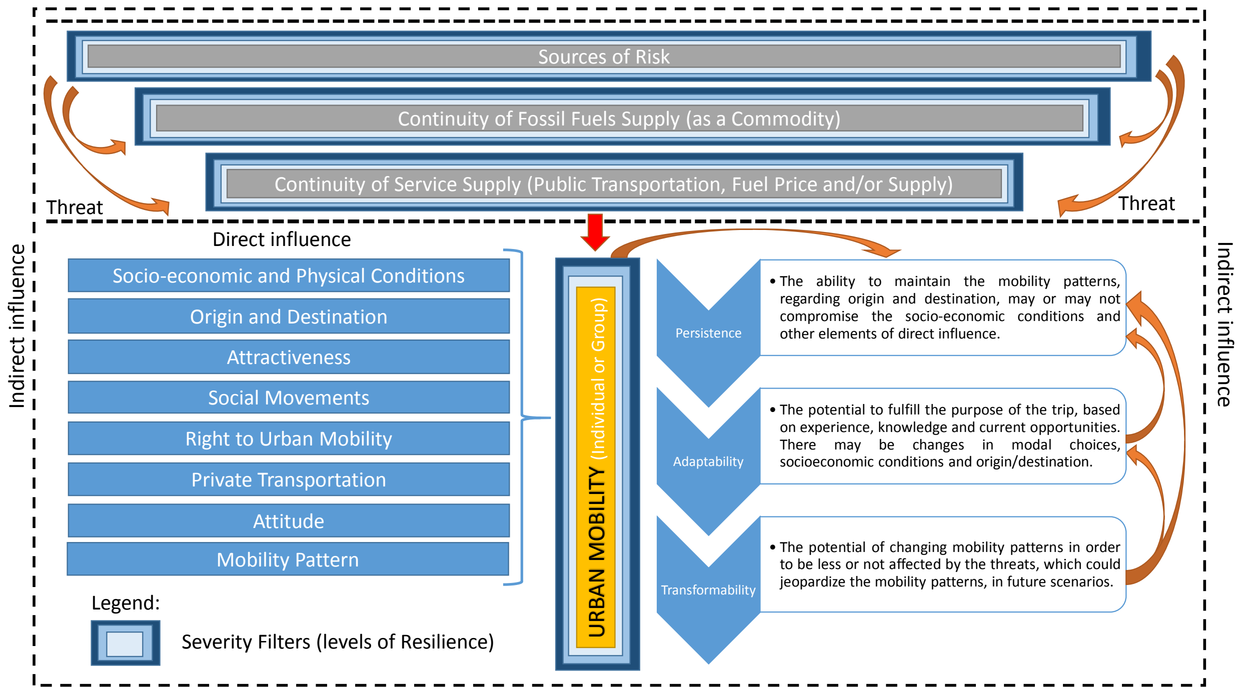


Figure 43: A Framework: Resilience of Urban Mobility

Based on the built conceptualisation of the resilience of urban mobility, from this section ahead, the discussion is aimed at the contribution of this concept within urban resilience. In addition, the following sections distinguish this concept from the sustainable mobility concept. Furthermore, as the main objective of this research, the aim is to test the conceptualisation and the framework, by developing a way to measure the resilience of urban mobility, through the development of a mix of qualitative and quantitative methodology.

CHAPTER 4

4. RESILIENT MOBILITY WITHIN THE URBAN RESILIENCE

This section aims at understanding the urban resilience concept and discusses the significance of resilient mobility within the urban resilience.

4.1. Urban Resilience Review

The urban resilience concept is relatively new (Collier, et al., 2013). According to Collier et al. (2013), the urban resilience concept involves a group of 12 elements of the urban context identified in Figure 44, which demonstrates the holistic approach of urban resilience, involving infrastructure, social-economic systems, space-temporal elements, policy's development, environment protection and human quality of life.

This holistic characteristic of the urban resilience concept has driven studies, in order to suggest improvements in urban policies, considering a more integrated and multi-disciplinary approach towards joining the interest of stakeholders and planners (Collier, et al., 2013) to improve the balance between environmental risks and citizens' quality of life.

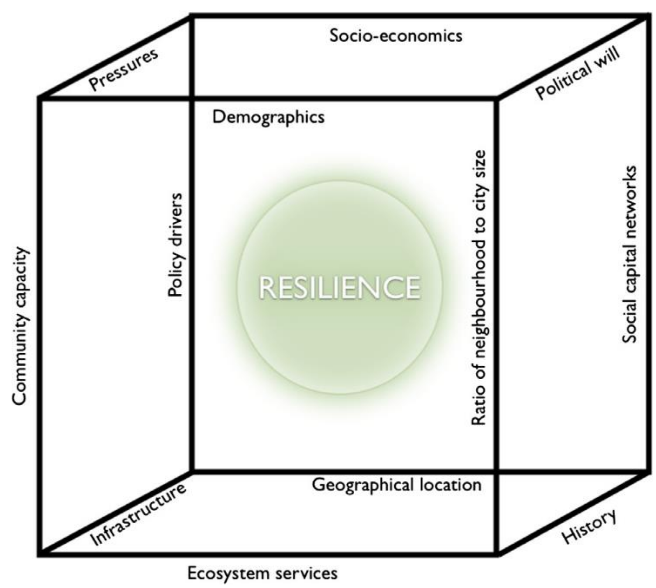


Figure 44: A stylised conception of resilience in an urban setting (Collier, et al., 2013)

Table 10 presents an overview of how the urban resilience concept has been defined by the extant literature. The sequence of authors is not in a specific order, it is ordered in the search and finding sequence. The intention is not to determine who defined the concept in the right or wrong manner, because each author considered suitable approaches for their own researches.

A certain complexity arises when dealing with urban and resilience concepts, as the urban environment is a complex space, which is composed of different "fragments", with different functions that articulate with each other through material and immaterial ways (Corrêa, 1995). Furthermore, inside the urban environment there are political, economic, social, cultural and environmental aspects that mould the city.

Regarding the resilience concept, it is a multidisciplinary concept, because of its wide range of possible definitions and applicability. Therefore, the objective of reviewing the authors' concepts in Table 10 is to comprehend the relationship between the objective of this research and the concept definition of each author.

Table 10: Concepts of Urban Resilience Found in Literature

Reference	Urban Resilience Concept Definition
Alberti et al. (2003); Collier et al. (2013)	The degree to which cities are able to tolerate alteration before reorganizing around a new set of structures and processes.
Leichenko (2011); Agudelo-Vera et al. (2012)	The ability of a city or urban system to withstand a wide array of shocks and stresses.
Vale and Campanella (2005);	The capacity of a city to bounce back from a significant obstacle.
Galderisi (2014)	Is the dynamic interplay of persistence, adaptability and transformability across multiple scales
Jabareen (2013)	It is defined by the overall ability of the city's governance. It includes physical, economic and social systems and entities exposed to hazards to learn from, being ready in advance, plan for uncertainties, resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner. This can be through the preservation and restoration of its essential structures and functions.

It is argued that there are studies that address the relationship between urbanisation and ecosystem dynamics, which do not represent the interaction between human and biophysical patterns and processes. Alberti et al. (2003) aimed his research on integrating humans into ecosystem science, through proposing a new conceptual model (Figure 45) that links human and biophysical drivers, patterns, processes and effects. This conceptual model can support scientists in understanding how the interaction between human and biophysical processes can affect the ecological resilience in urban ecosystems.

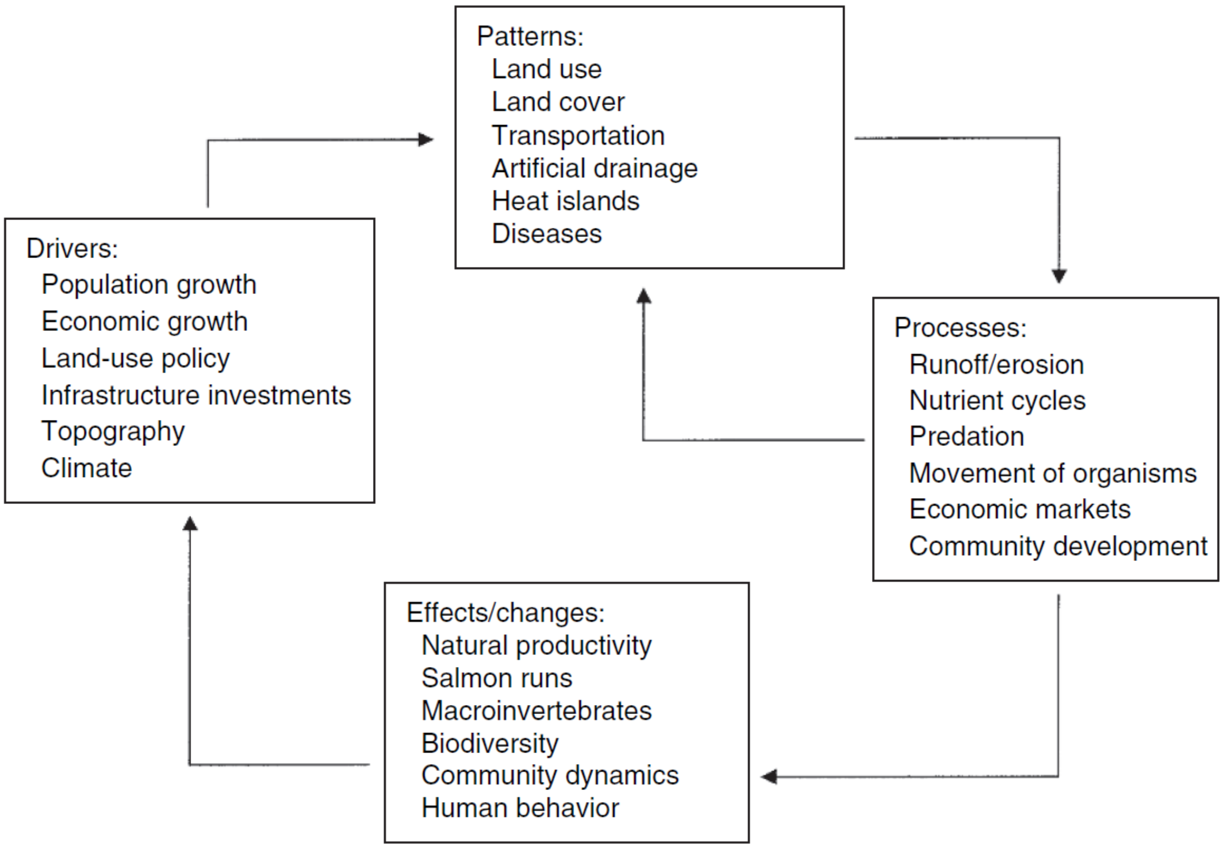


Figure 45: Conceptual Framework of Urban Ecological Resilience (Alberti, et al., 2003)

Collier et al. (2013) focus on outlining emerging challenges towards operationalising how cities might transition to a more resilient future, while ensuring that communities are at the centre of the process. In order to improve, from a practical point of view, the transition of cities towards more resilient environments, Collier et al. (2013) proposes an improvement on six specific tools that could strengthen urban resilience:

1. Use of Geospatial Information and Communication Technologies (G-ICT), with integrated and accessible datasets, generates conditions to develop spatial data infrastructures, which can support the development of policies oriented to improve

urban resilience and sustainability. Moreover, it can also be a tool to give citizens and private sectors access to data, thus adding them on the policy's development process

2. The propagation of green infrastructure in public and private sectors, e.g. green roof technology. "Green infrastructure can be designed to maximize the biodiversity, ecosystem services and carbon storage value of green spaces" (Collier, et al., 2013, p. 24).
3. Encourage collaborative processes. "Urban communities must be seen as the central stakeholders in transitioning objectives" (Collier, et al., 2013, p. 24). Transition policies towards more resilient cities must be a process that considers the interest of usual stakeholders (e.g. companies, organisations, research institutions, etc.) and "weaker" stakeholders (citizens). "Citizen-led planning entails a fundamental shift in the planning paradigm with the focus on facilitating communities in creating a concept for their future needs and wishes, while seeking to work with planning stakeholders on an egalitarian level." (Collier, et al., 2013, p. 24)
4. Operationalise climate-resilient city planning. "Holistic and strategic energy planning strives to reduce end-use energy demand and adopt urban energy supply systems for increasing shares of renewable energy, thereby strengthening urban energy resilience through lower long term costs of running urban energy systems. However, new infrastructure measures, either energy or water related, need to be implemented through urban planning and land use management." (Collier, et al., 2013, p. 25)
5. Development of policies to limit urban sprawl, with a better understanding of cities, at the local, regional, national and worldwide scale. Therefore, aiming for developing more compact, complex, functional and socially integrated cities, which would stimulate polycentricity (decentralised concentration), a functional network of cities that generates "cooperation between urban areas as a means to achieve physically and functionally connected regions" (Collier, et al., 2013, p. 25).
6. Transition to short-circuit economies through the combination of manufacturing firms with service sectors towards "Green Servicing" (Collier, et al., 2013, pp. 25-26). "This is an emerging concept and is a business model devised and developed in academia and aimed at providing sustainability of both consumption and production" (Collier, et al., 2013, pp. 25-26). "Emerging economic tools and innovation opportunities have

now a vital role in resilience planning, as well as offering an opportunity to embed resilience in communities" (Collier, et al., 2013, pp. 25-26).

Although both papers, Alberti et al. (2003) and Collier et al. (2013), present the same urban resilience concept (Table 10), they use it on different approaches. While Alberti et al. (2003) uses it to state the importance of developing a model that focusses on improving the ecological resilience in urban environments, Collier et al. (2013) presents the concept of urban resilience introductorily to further propose measures, based on his bibliographic review, which can improve urban resilience, facing climate change, energy and social issues.

Based on the increasing use of the urban resilience concept between 1990 and 2011, and because of the lack of studies that places the urban resilience concept at the centre of their analytical focus, Leichenko (2011) wrote a paper aiming at identifying themes, which are addressed in studies that relate urban resilience and climate change. According to Leichenko (2011), urban resilience studies can be broadly sorted into four categories and definitions:

1. Urban ecological resilience – "The ability of a city or urban system to absorb disturbance while retaining identity, structure and key processes" (p. 164);
2. Resilience to urban hazards and disaster risk reduction – "The capacity of cities, infrastructure systems, and urban populations and communities to quickly and effectively recover from both natural and human-made hazards" (p. 165);
3. Resilience of urban and regional economies – The ability of urban and regional economies to quickly recover from disturbances caused by humans and nature;
4. Resilience through urban governance and institutions – The effects of different types of institutional arrangements and government policies on urban resilience.

Summing up his review, the urban ecological resilience regards the extreme climate events and gradual climatic changes as shocks that affect the human and ecological environment, as presented also by Alberti et al. (2003). Urban hazards and disaster risk reduction regards many issues that can compromise urban functioning, such as climate change, terrorism and natural disasters (e.g. hurricane, earthquake and flood).

Studies that emphasise the resilience of urban and regional economy are rooted in economic geography and urban and regional planning. It is a field that identifies factors that explain why resilience is uneven across places and locations and examines linkages between resilience and long-term growth and/or decline of cities and regions, faced with human or natural factors.

Resilience of urban governance and institutions addresses the characteristics of urban governance that can enhance, e.g. climate resilience, thus reducing vulnerability of urban citizens who are exposed to climate-related shocks.

Cities, currently, are highly dependent on each other and hinterlands to supply materials and energy and to dispose waste. The logistics of this dependency, possibly, are not sustainable, because they do not use resources efficiently. According to this argument, Agudelo-Vera et al. (2012) presents three objectives. First is the concept of urban harvesting. The second and third are, respectively, to quantify the potentials to harvest water and energy at the national and neighbourhood scale.

Agudelo-Vera et al. (2012) believe that urban harvesting is a tool for planning resilient cities, because it places resource management as the key factor for sustainable urban planning to close open links between sources and demands. The concept of urban harvesting deals with a cyclical process. It involves strategies to harvest primary and secondary resources that are locally available and renewable (e.g. harvesting of rainwater or solar energy). It harvests the remaining flows, re-uses low quality resources for lower quality demanding purpose (e.g. using wastewater from the shower to flush the toilets or harvesting the remaining heat in shower water) and upgrades the quality of the remaining resources by recycling.

Leichenko (2011) and Agudelo-Vera et al. (2012) present the same definition of urban resilience (Table 10), but on the one hand, Leichenko (2011) focusses on identifying lines of research, which addresses urban resilience, faced with climate change, presenting definitions for each type of urban resilience (related to ecology, urban hazard, economy and policies). On the other hand, Agudelo-Vera et al. (2012) focus on measuring the energy and water resilience at the national and local scale and propose urban harvesting strategies as a tool to improve urban resilience.

In the book of Vale and Campanella (2005), *The resilient city: How modern cities recover from disaster*, the focus is on urban resilience faced with urban disasters, such as those originating from fire, earthquakes, floods, hurricanes, industrial and nuclear accidents, epidemic diseases, civil wars, international wars and terrorism.

According to Vale and Campanella (2005), an urban disaster can be categorised, basically, by three aspects: scale, damage and origin of destruction. Vale and Campanella (2005) regard resilience as the recovery process from non-predicted disaster and from those that may even be predicted, but not avoided. Their book discusses some of the urban disasters that happened over the past years. These include the Chicago fire of 1871, San Francisco earthquake of 1906, terrorist attacks in Oklahoma City and New York, respectively, in 1995 and 2001, the British invasion of Washington, D.C. in 1814, Mexico City's 1985 earthquake and Berlin's destruction in the Second World War.

As the types of disasters cited by Vale and Campanella (2005) were hardly predictable, they believe that for these kinds of events it is difficult to find patterns. Despite this difficulty to establish a systematic analysis of post-disaster recovery, the authors bring up a model of disaster recovery that could be more suitable for their approach on urban resilience. This model consists of four stages (Figure 46): Emergency (1); Restoration (2); Reconstruction I (3) and Reconstruction II (4).

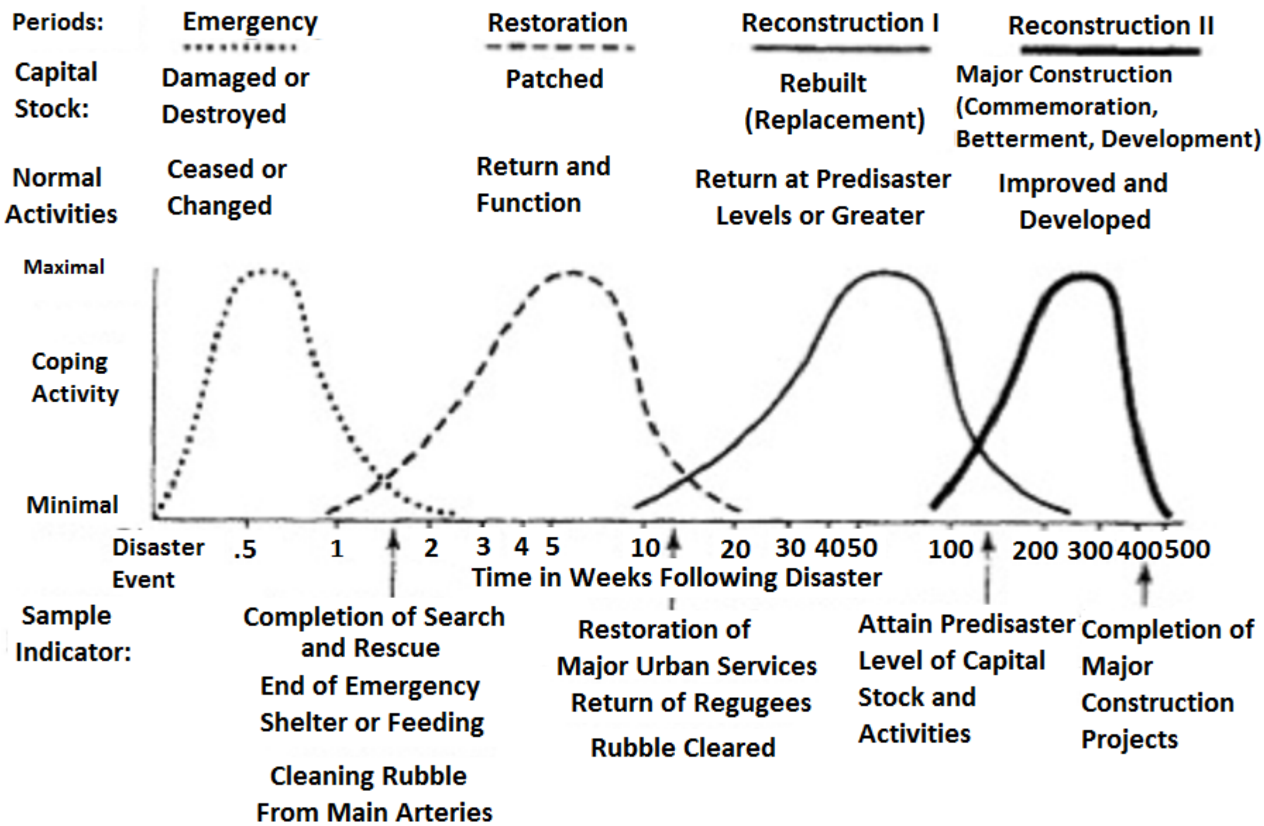


Figure 46: Model of post-disaster recovery (Vale & Campanella, 2005, p. 337)

According to the Figure 46, the emergency phase deals with the effort to cope with the injured, loss of life and debris (consequences of destruction). In addition, this first period after the disaster, can in some cases, be characterised by a drastic change or even a cease in economic and social activities. The second phase (restoration) regards the reestablishment of major urban services, utilities and transport. The third phase (reconstruction I) aims to rebuild capital stock to pre-disaster levels and stimulate the growth of population, to reach the population level presented before the disaster. In the fourth phase (reconstruction II), the disaster is overcome by completing major construction projects that would return the prosperity and sociability.

Vale and Campanella (2005) deal with resilience more as an elasticity than as a toughness approach. Their view on urban resilience is towards the capacity of a city to recover from unpredicted events, which can affect the city in unpredictable places, at an unpredictable scale and damage. This unpredictability can be a reason to believe that the period after the event is when the cities show their level of resilience, by recovering to its previous conditions (before the disaster).

Galderisi (2014) reviews the concept of resilience applied to ecology and sustainability, risk and disaster, economy, and climate change and identifies common concerns (Figure 47) amongst the disciplinary fields in relation to the types of capacity considered. This author makes a similar review as Leichenko (2011) and Béné (2014), regarding each type of resilience study in urban environments, with the intention to generate an urban resilience framework, concerning urban resilience as a process. Galderisi (2014) states that this framework (urban resilience model):

> *Should be calibrate on specific urban systems, in order to: prioritize the capacity placed at different levels of the model according to the real problems of the city at stake; define tailored on the context actions and measures to be implemented in order to achieve each capacity (p. 53).*

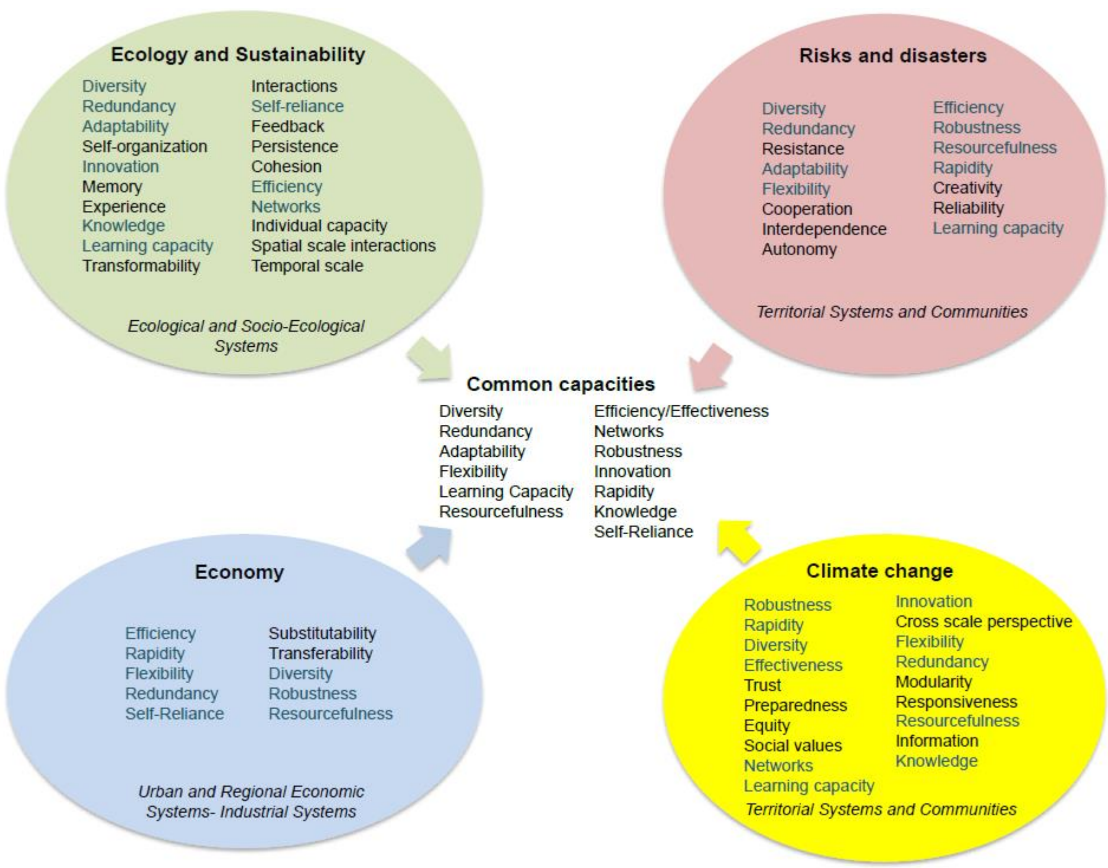


Figure 47: The capacities of a resilient system according to different disciplinary approaches and the set of common capacities (Galderisi, 2014)

According to Galderisi (2014), the urban resilience can be seen as “a cyclical process formed by three stages mirroring the response of an urban system to an external stress” (p. 47): Pre-event phase, emergency phase and recovery/transition phase. The developed framework (Figure 48) aims to enhance urban resilience, by reaching the core of the framework (most internal part of Figure 48). At the second level of the framework, five capacities’ factors are placed, based on the common capacities presented on Figure 47. Each of the capacities is defined by Galderisi (2014, pp. 48-52), hereafter:

- Robustness – “The capacity of an urban system to withstand external threats, preserving its physical, environmental and social capital without significant reductions in its ordinary level of functioning” (pp. 48-52);
- Efficiency – “The capacity of a system to guarantee its performances in a resource-limited setting” (pp. 48-52);
- Diversity – “The preservation of the key assets as well as the key functions of an urban system in case of impacts of adverse events” (pp. 48-52);
- Innovation – “The ability of a system to reorganize its variables in response to an external change” (pp. 48-52);
- Learning Capacity – “The capacity of an urban system to learn from past events is a key-step for anticipating, foreseeing and coping with the future ones” (pp. 48-52).

The third level of Figure 48 specifies a set of capabilities that are related to the five capabilities presented. Galderisi (2014) intends, with her work, to present a framework of urban resilience that can serve as a tool for planners and decision-makers “to overcome some of the weaknesses of current disaster mitigation strategies based, in most cases, on a sectorial perspective and often focused on physical failures” (pp. 48-52).

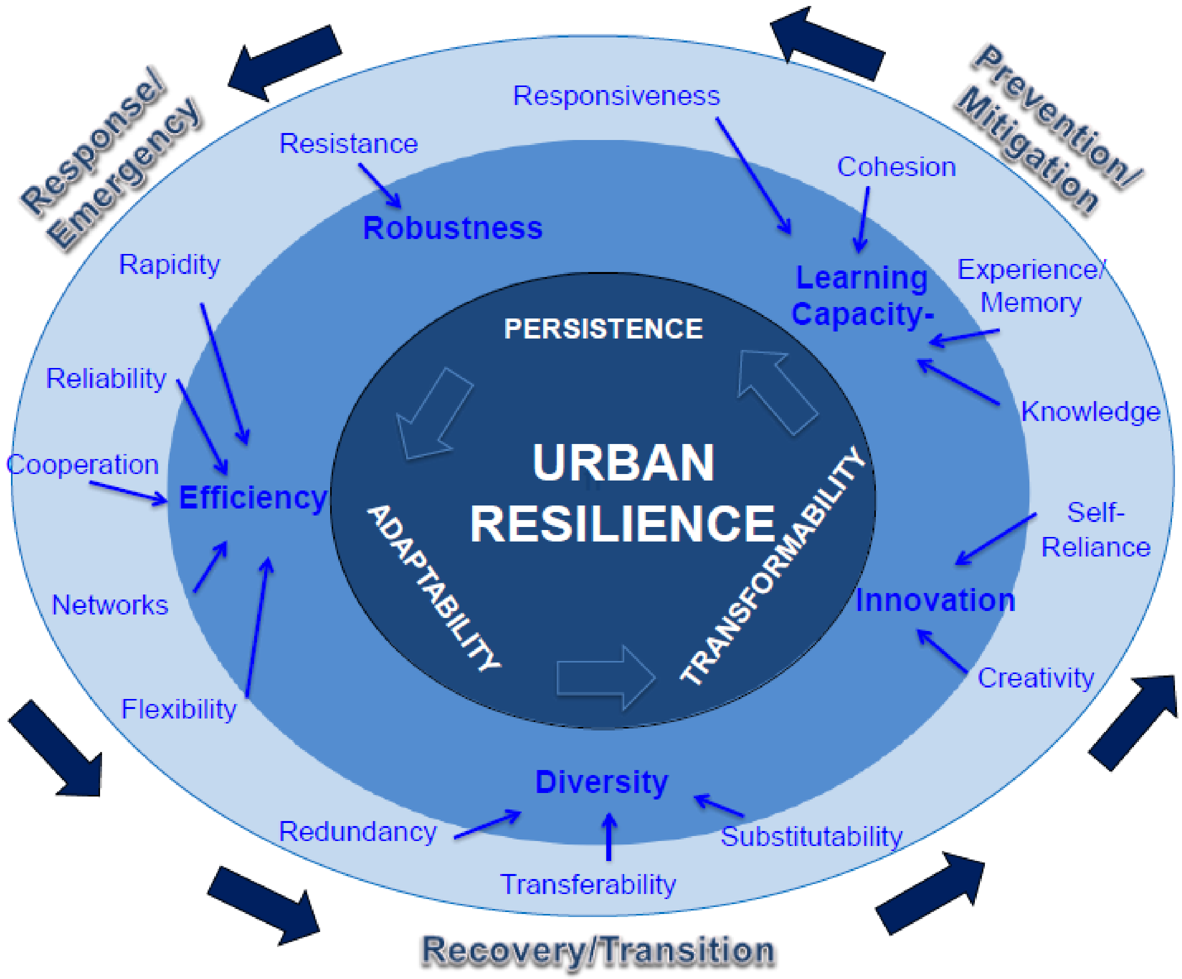


Figure 48: The integrated model of Urban Resilience (Galderisi, 2014)

Although the framework (Figure 48) considers diverse elements of the urban environment, the urban space is well known for its complexity. Moreover, the authors did not apply any case study to show the practical utility of the framework.

Based on the background and reading experience of the author of this thesis, it is observed that scholars who pursue the understanding of the impact of economic, environmental, political, cultural and social changes on the city, have difficulties in identifying each and every affected elements of the city. It is common that urban studies are fragmented in a diversity of scientific fields, in order to have a better understanding of each impacting element, based on the background of the scholar who develops the respective study.

Jabareen's (2013) objective is to build a Resilience City Planning Framework (RCPF), in order to contribute to the filling of the theoretical and practical gaps in the city resilience literature. The framework (Figure 49) developed by Jabareen (2013) is composed of four interrelated concepts and their components, which are shown as follows:

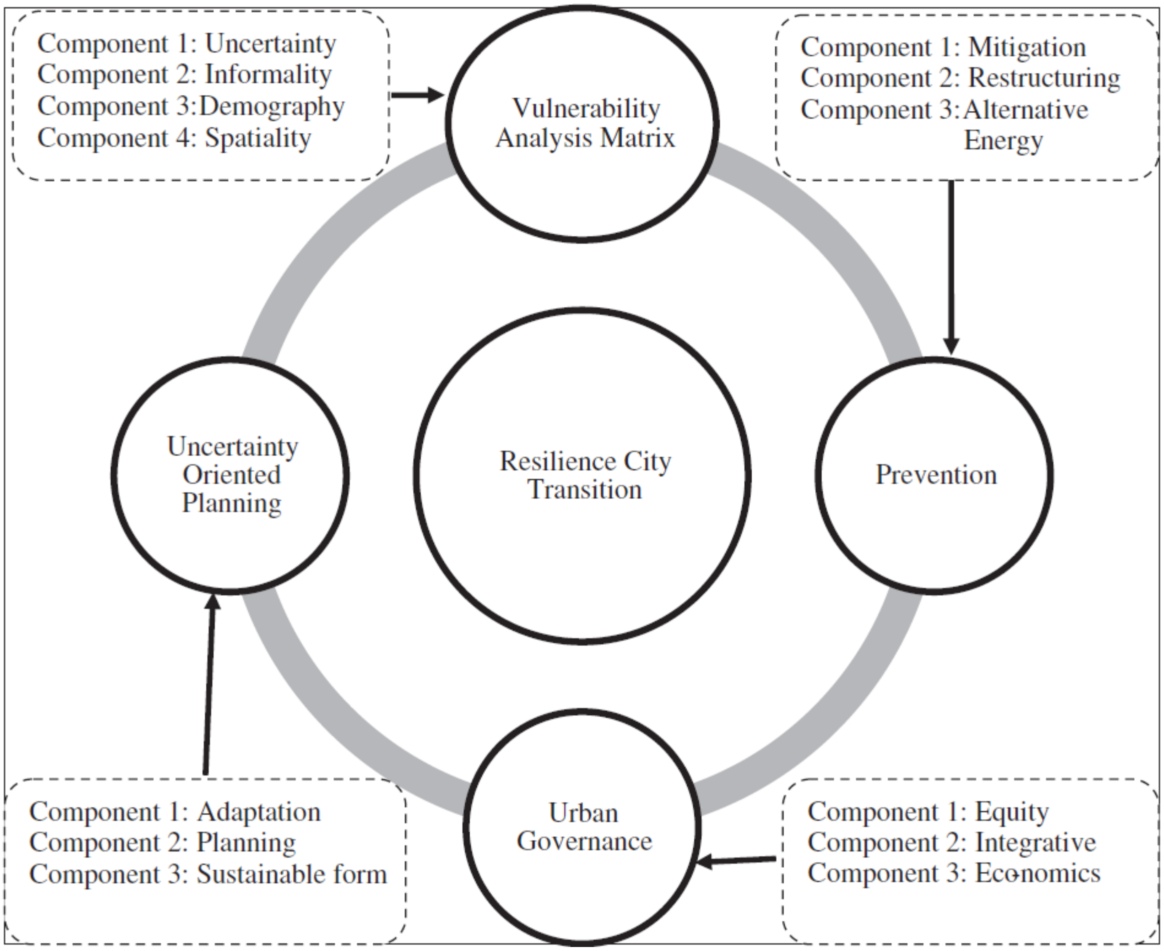


Figure 49: Resilient city planning framework (Jabareen, 2013)

As Figure 49 shows, the four concepts are Vulnerability Analysis Matrix; Urban Governance; Prevention and Uncertainly Oriented Planning. The vulnerability analysis matrix involves geographical distribution (component 4) of socioeconomic conditions (component 3), informal urban spaces (Component 2) and uncertain events (component 1).

The urban governance is composed of three components. They are as follows: level of social inequity (component 1); participation of different stakeholders and agents, e.g. public, private, civil institutions and organisations (Component 2) and application of climate change mitigation and sustainable solutions (Component 3), by stimulating markets for environment-friendly products and services and promoting eco-friendly consumption.

The prevention concept seeks to prevent environmental hazards and climate change effects. It is composed of three components: policies and actions that aim to reduce greenhouse gas emissions (GHG) (Component 1), the ability and flexibility of a city to restructure itself in order to face social, environmental and economic challenges (Component 2) and access to clean and affordable energy (Component 3).

The last concept is uncertainty-oriented-planning, which is composed, also, of three components. The first is climate change adaptation, which should address uncertainties and limit impacts even if magnitude and direction are uncertain or unknown (Component 1). The second is spatial planning in a macro urban dimension regarding physical security and environmental and socio-spatial policies, including prediction and anticipation of risks (Component 2) and lastly, the sustainable urban form (component 3), which deals with urban design and the qualities of urban form.

The RCPF developed by Jabareen (2013) is oriented objectively to urban elements, urban governance, social-economic, environmental and energy issues. However, it is still an overall framework, as observed also by Galderisi (2014), and within an urban environment, with such complexity, it does not seem applicable, considering the complexity within infrastructural, social, economic and environmental issues. On the other hand, an overall urban resilience framework helps decision makers to understand the interrelationship between urban elements and the way in which they affect each other.

4.2. Resilient Mobility: Contributing to Urban Resilience

Through the literature review of the previous section (4.1.), it is observed that scholars focus on the urban resilience concept that can undertake several meanings, e.g. when dealing with natural disaster, natural resource shortage, geopolitical conflicts and other issues. Furthermore, the meaning also varies, depending on which elements of the urban space is the object of study, as vulnerable to a specific threat.

Within the complexity of urban resilience, the resilience of urban mobility contributes as a part of the total. According to the Galderisi (2014) view of urban resilience, it can be observed that the resilient mobility approach contributes to preserve one of the key functions of the urban system, which is mobility itself, in terms of reducing the vulnerability of this element towards an energy crisis, such as fuel supply shortage or price increase.

Through Jabareen's (2013) perspective, resilient mobility is inserted in the interest of the four concepts that compose of urban resilience. Firstly, because it involves the understanding of the geographical dimension of the problem, in terms of the socioeconomic impacts, faced with a threat. Secondly, because the mobility issues deal with the accessibility of different social classes to the transportation infrastructure, the actors are responsible for implementing transportation systems and climate change issues, when regarding environmental impacts. Thirdly, the mobility is strongly related to the emission of GHG, a field that demands challenges regarding the change of energy source, under different social, economic and environmental conditions. At last, it deals with prediction of threats and socio-spatial policies in order to build a sustainable urban form and avoid future threats.

From these perspectives, it is observed that the resilience of urban mobility is a concern within urban resilience. In addition to the discussion, during the development of the understanding of the resilience of urban mobility, a question that came up is, "how does resilient mobility distinguishes itself from sustainable mobility?"

CHAPTER 5

5. DIFFERENCE BETWEEN RESILIENT MOBILITY AND SUSTAINABLE MOBILITY

This section's objective is to review the concept of sustainable mobility and show its difference from the concept of resilience of urban mobility. Furthermore, it discusses how these concepts can complement each other.

5.1. Sustainable Mobility Review

The number of discussions regarding sustainability issues has been growing significantly in the last years. According to Hassan et al. (2014), many countries and international organisations have adopted sustainable development and its various sub-areas as national priority. This statement is based on a bibliometric study developed by Hassan et al. (2014), which consists of a search based on keywords related to sustainable development approaches in researches and reports.

Initially, Hassan et al. (2014) identified common topics within sustainable development issues between the World Bank, OECD (Organization for Economic Co-operation and Development) and UNDESA (United Nations Department of Economic and Social Affairs). The common topics addressed amongst these three organisations are climate change, agriculture, biodiversity, water and transport (Figure 50). In terms of relevance, it is possible to observe that the transport topic belongs to a common concern amongst these organisations.

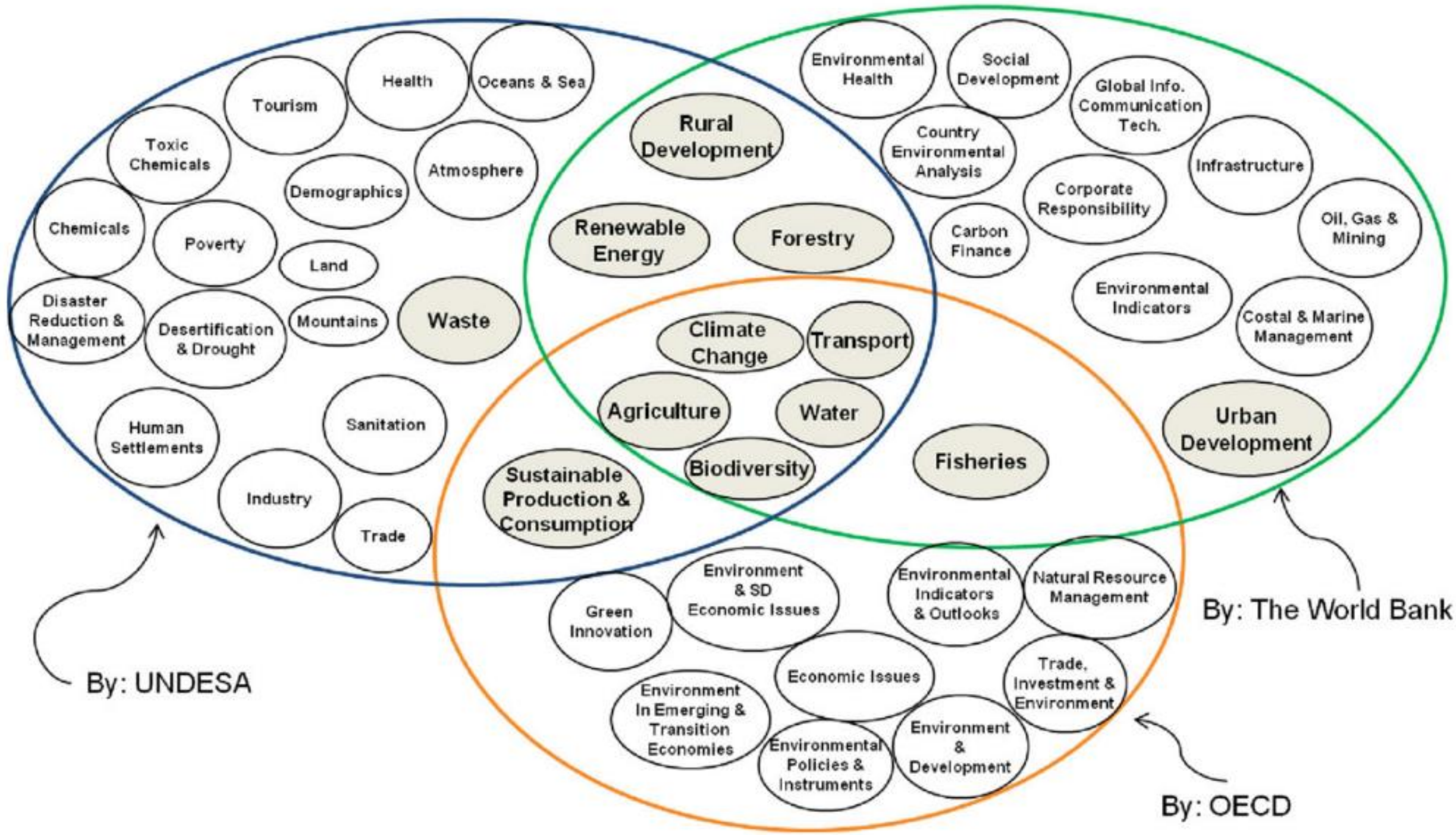


Figure 50: Sustainable Development taxonomies by The World Bank, UNDESA and OECD (Hassan, Haddawy, & Zhu, 2014, p. 553)

Sustainable approach has been introduced in urban mobility in the last few years, as discussed above. Hassan (2014) and Jones' (2014) research restates the issue. Banister (2008) discusses the sustainable mobility paradigm under the context that the majority of transport solutions to urban problems and growth of faster and longer travelled distances are explained through two fundamental principles. These are embedded in mostly analysis and evaluation studies: travel is a derived demand and not an activity that people wish to undertake for its own sake (Banister, 2008) and that people minimise their generalised costs of travel, mainly operationalised through a combination of costs of travel and the time taken for travel (Banister, 2008).

There is a contradiction between the interest of sustainable mobility today and cities' growth, because of the tendency in maintaining travel time. However, distance and speed have increased substantially. In this urban development context, public transport, cycling and walking have become less attractive and dependency on motorable transport like cars has increased. From Banister's (2008) point of view, "sustainable mobility provides an alternative paradigm within which to investigate the complexity of cities, and to strengthen the links between land use and transport" (p. 73).

Based on the first fundamental principle used in developing transport solutions mentioned by Banister (2008), it has been argued that it is not possible to think of travel as a derived demand, according to the new technologies. Presently, people have the option to replace travel for online activities. Therefore, there is a transfer of power from the producer to the consumer. Furthermore, "increasingly, users will control their leisure and shopping activities tailored to their own specific requirements" (Banister, 2008, p. 74). For this reason, mobility solutions can't only consider improving speed and transportation issues from an origin-destination path, based on work trip. Due to the constant improvement of technologies in transportation and communication, a new logic of mobility and land use is being generated. It seems like people will tend to save more time and use it for spontaneous travel, which is not predictable in time and space.

The second principle, regarding travel-time minimisation, is argued by Banister (2008). He points out the contradiction of travel-time minimisation in the urban environment, which is represented by new low speed limits introduced together with speed cameras, based on environmental and safety reasons. He believes that "the notion of a transport system without congestion has never been a realistic objective" (2008, p. 74). Thus, recent policies are aimed at determining a reasonable travel time, rather than time minimisation. Moreover, there is a dependency of people and businesses on having the information of "…how much time it should take to travel to their destination with a reasonable degree of certainty" (Banister, 2008, p. 74). This means that there is excessive reliability of people in the system.

The need to generate more sustainable conditions for the possibility of multi-directional movement in the urban environment, in order to improve the quality of spontaneous trips and reduce car dependency can be taken under consideration. The desirable time that would be spent in the movement process from the citizens' perspective gives options, instead of imposing time expectations. Depending on the destination and activity, speed, perhaps, is not the desirable way, and vice versa. Both arguments are a step forward to change the approach towards mobility solutions, migrating the policies from traditional transport planning to a sustainable approach.

Attempting to contribute to the sustainable mobility approach, Banister (2008) identified four main elements that should be taken under consideration, when developing sustainable urban mobility policies, which are quoted hereafter:

- "Making the best use of technology, including investment in technology, in transport modes, information systems and in the transport system itself, and in giving industry directions on priorities (e.g. on hybrid and fuel efficient vehicles and alternative fuels)." *(p. 78)*
- "Regulation and pricing means that the external costs of transport should be reflected in the actual costs of travel through higher fuel prices or through some form of road user charging." *(pp. 78-79)*
- "Land-use development, including planning and regulations, needs to be integrated, so that physical restraint measures and development patterns are used to support shorter travel distances." *(p. 79)*
- "Clearly targeted personal information, including social pressure, awareness raising, demonstration, persuasion and individual marketing, is also crucial." *(p. 79)*

The first element regards the improvement in the technological aspects of vehicles and considers the implementation of renewable energy use. The second element targets the private car users, adding actual external cost to these users, which would represent monetary values of the environmental impact caused by private transportation. The third element includes the concern by encouraging the development of mixed and compact land-use, consequently improving sustainable mobility by reducing the distance travelled, leading to trip reduction and modal split changes. The fourth element is indirectly related to the other three, because it deals with public acceptability. It is not possible to make legal (law) or infrastructural changes if people are not willing to adapt. Thereby, there must be policies addressed to informing and encouraging adaptation among those who are directly influenced by urban mobility policies in their daily lives.

Through his review, Banister (2008) identified seven key elements that can support the improvement of public acceptability towards sustainable mobility policies. Table 11 presents these key elements. To reach a high level of public acceptability, it is recommendable to develop sustainable mobility policies as a participatory process. This way, people and companies would tend to understand that benefits could go beyond costs or time.

Table 11: Key elements in promoting the public acceptability of sustainable mobility

Elements	Focus
Information	• Education, awareness campaigns and promotion through media and social pressure are an essential starting point. • Explanation of the need for sustainable mobility, emphasising the positive economic, social and health benefits to the individual and businesses.
Involvement and communication	• The process must be inclusive, with clear aims and an understanding of the consequences to those on whom the strategy will affect. • Designed to gain support and understanding, so that stakeholders can buy into the proposals. • Raise levels of consistency between expectations and outcomes.
Packaging	• Push and pull policy measures needed to be combined in mutually supporting packages. Policies restricting car use or raising its costs should be accompanied by well-publicised programs to improve the availability and attractiveness of alternatives to driving alone, including carpooling, public transport, cycling and walking, all financed by dedicated revenues from car pricing measures.
Selling the benefits	• It is necessary to publicise the benefits widely, even if there are costs, inconvenience and sacrifice. Car drivers support the funding of alternative modes to reduce congestion on roads on which they drive. Overweight or obese individuals would directly benefit from better walking and cycling. Everyone benefits from cleaner air and safer traffic conditions. More walking, cycling and public transport use would help relieve parking shortages. All individuals can support these important and direct effects.
Adopt controversial policies in stages	• Support needs to be built up in terms of positive outcomes and measurable improvements in the quality of life. • Politics is about reflecting prevailing preferences and forming opinions. Acceptance of responsibilities and commitment to change through actions is the key to success.
Consistency between different measures and policy sectors	• Some measures (e.g. pricing) that are common to all futures. Such measures need to be implemented now, even though their effects may not be immediate. • Regulations, standards, subsidies and tax incentives should all be used to encourage manufacturers and other transport suppliers to develop and adopt the most energy-efficient and environment-friendly technology possible. • The precautionary principle should be followed, particularly on the global warming effects of transport emissions and actions should be consistent over the long term. • Many of the problems created for the transport system do not emanate from the transport sector, but from other sectors. So a more holistic perspective is needed that integrates decision-making across sectors and widens the public discourse.
Adaptability	• Decisions today should not restrict the scope for future decisions, such that the adaptive behaviour of individuals and agencies can be assessed. • There is no prescription or blueprint for the correct procedures to follow. Each situation requires separate analysis and implementation, including flexibility to change policy measures if intentions and outcomes do not match up. Assessment of risk and reversibility are both strong components of sustainable mobility. • Adaptability is not an excuse for inaction or weak action. It is an argument for clear decision making, leadership, supported by analysis and monitoring to check on the effectiveness of policy action.

Source: adapted from Banister (2008).

To continue the discussion, Vale (2013) develops a study based on the belief that sustainable urban development policies, which intend to promote mixed-use suburban centres, can reduce car dependency and encourage sustainable mobility. He developed a binary and multinomial logistics model to identify variables that affects commuters' behaviour. Through a combined analysis of commuting mode, time and distance, Vale (2013) demonstrates a commuter's behaviour towards workplace relocation.

Vale (2013) applied his methodology in the Lisbon Metropolitan Area (LMA) in Portugal, analysing workers' behaviour before and after their work relocation to a new, mixed-use, transit-oriented suburb. Although the representativeness of the sample size of his case study could not be assured, the study still showed unexpected results regarding commuting pattern. On one hand, from his case study, those whose work was relocated to distant places, the majority changed from public transport to private car use, and took more time to get to their destination. On the other hand, the majority of people who relocated to closer places, with a higher level of mixed land use and public transportation availability, did not change the commuting pattern to public transportation use, but kept using private vehicles to go to work and the commuting time, surprisingly, maintained the same.

Vale (2013) points out that the development of a mixed-use centre in LMA, plus the improvements in the accessibility by public transport has attracted a considerable number of companies to relocate to the site. However, for those who changed the workplace from a farther to a closer distance, there is low interest of changing to the sustainable commuting pattern. The author argues that a decrease in commuting distance, initiated by the creation of mixed use, the accessible suburban centre is not enough to trigger a change to a more sustainable transport mode.

By reviewing Vale (2013) and Banister (2008), it can be observed that a common point has been reached in both works, in different ways. While one writes an extensive literature review on the sustainable urban mobility paradigm (Banister, 2008), the other develops a mathematical approach, which tests the sustainable urban development logic (Vale D. S., 2013). Therefore, the improvement of sustainable mobility involves a set of elements, which includes urban design, mixed land use, transportation infrastructure and technology, mobility policies and public acceptability.

5.2. The Difference between Concepts: Sustainable Mobility and Resilient Mobility

The raise of the sustainable mobility concept is strongly related to the need to reduce the use of non-renewable energy source and environmental impacts. Through this objective, we observe the effort to address ways to reach the main energetic and environmental goals and furthermore, improve the social aspects, without jeopardising economic conditions.

From this perspective, the sustainable mobility concept has been developed towards including many social, economic and environmental aspects. Currently, there is an extended list of solutions related to building a sustainable mobility (Goldman & Gorham, 2006), such as distributed travel information, fare integration, carsharing, bikesharing, auto-free housing, and intelligent transport management and liveability.

It is possible to observe that from an overall view, sustainable mobility is concerned with environmental impacts, economic impacts and social equity (Nicolas, Pochet, & Poimboeuf, 2003), as is shown in Figure 51.

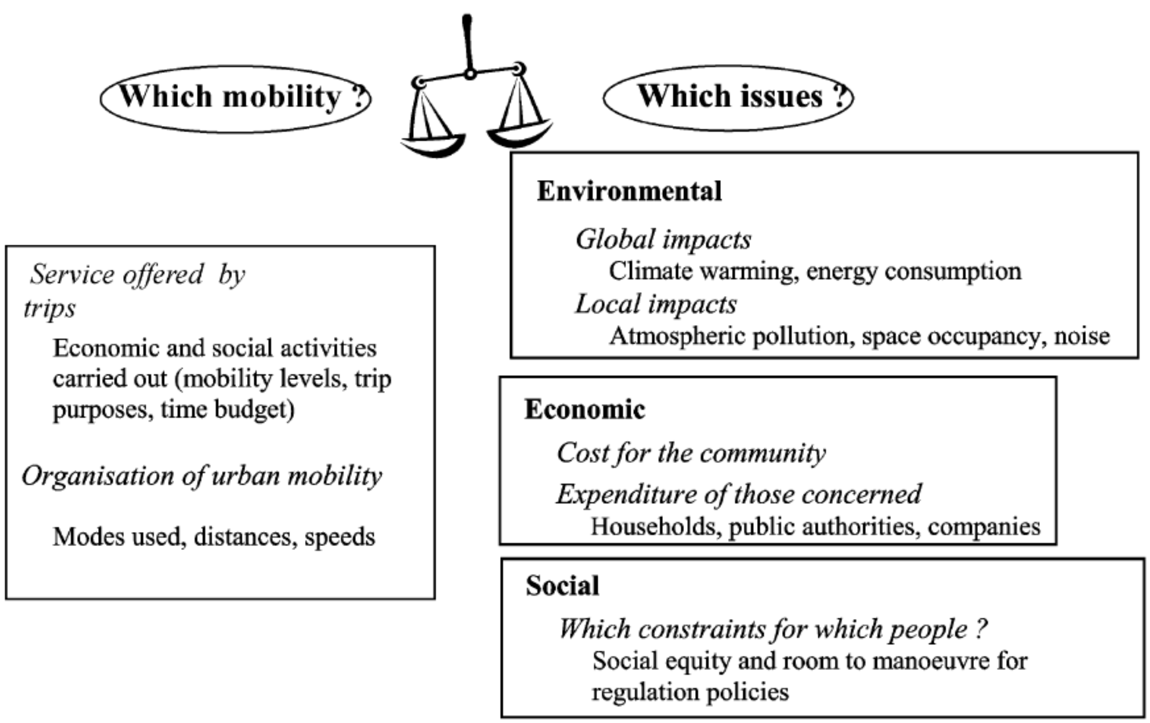


Figure 51: Mobility and its sustainability challenges (Nicolas, Pochet, & Poimboeuf, 2003, p. 201)

Based on the resilient mobility concept built in this thesis, Figure 52 is drawn, in order to illustrate the difference in the main concerns within the sustainable and resilient approach. It is understood that a resilient approach aims at determining a possible threat to the system, and the effect of the threat is mainly on social and economic aspects. The sustainable concerns regard the implementations of technological solutions that improve social equity, allowing economic development and reducing environmental impacts.

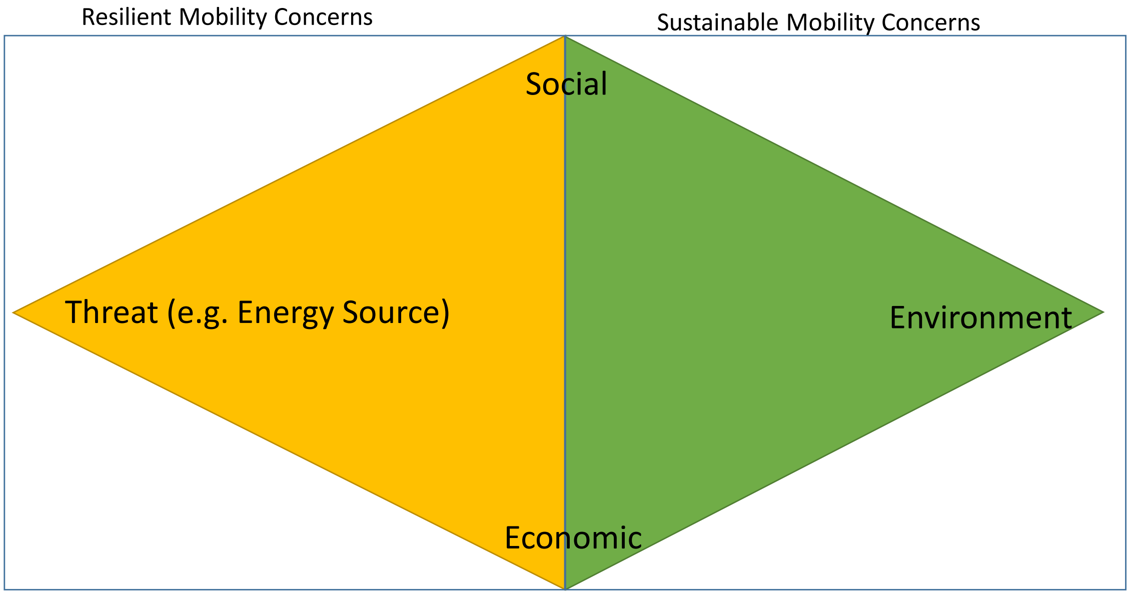


Figure 52: Main concerns of Resilient and Sustainable Mobility

Through this perspective of concerns shown in Figure 52, the social and economic concerns intercede, and those concerns, which do not intercede, can complement each perspective. This means that, to be resilient, can also mean sustainable, and to be sustainable can mean to be resilient. However, it can be the other way around as well, in other words, one approach may not be necessarily linked with the other one, if there is not complementary planning and policymaking.

CHAPTER 6

6. THE RESILIENCE OF URBAN MOBILITY: METHODOLOGY OF EVALUATION

This section suggests a way to measure the resilience of urban mobility based on the built concept and framework (see chapter 3.7.2. and Figure 43). As basis of this research, the urban space is seen as an ecological unit, based on the School of Chicago. However, it locates the social approach on the centre of the system, as suggested by Castells (2009).

Figure 53 presents the system of resilience of urban mobility, faced with fossil fuel dependency, which is illustrated as "threat" in the figure. This system is composed of three stages (persistence, adaptability and transformability), which are interrelated.

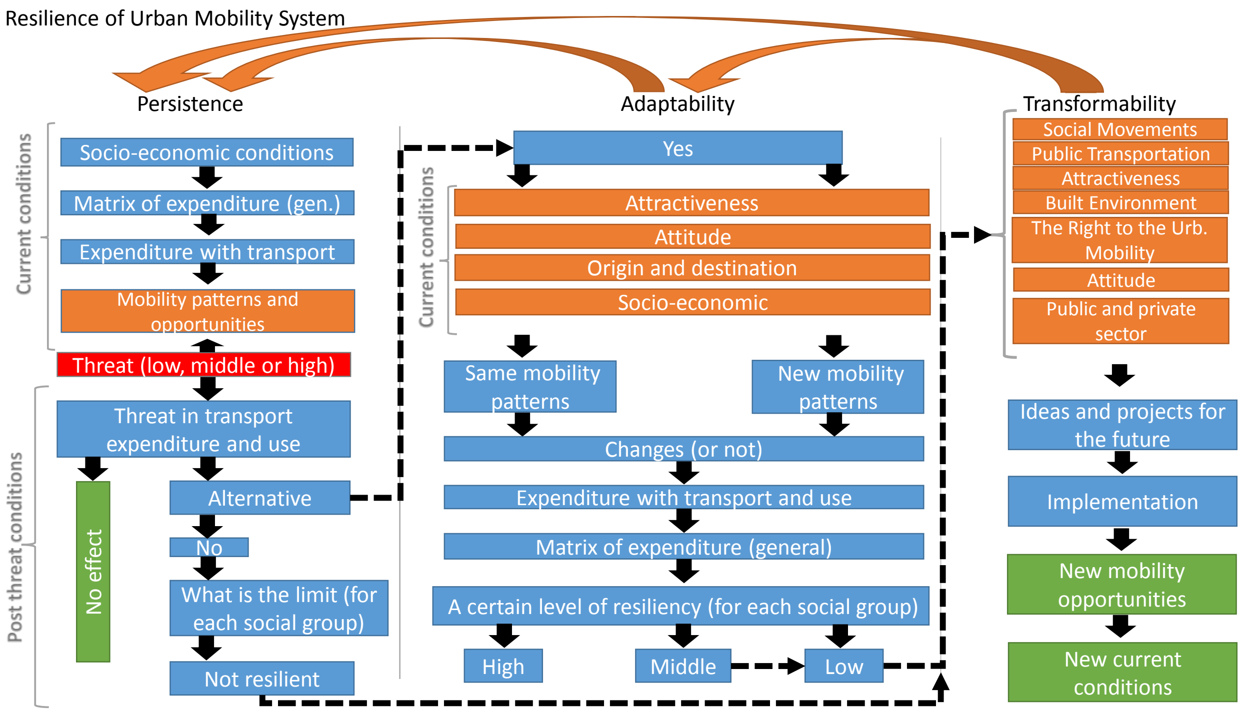


Figure 53: The system of the resilience of urban mobility

In order to build an organised process of evaluation and analysis, this research follows a certain order of the presented system, beginning with the persistence stage, which is composed of the description of current conditions of mobility patterns, socioeconomic conditions, matrix of expenditure and expenditure with transportation. Hereafter, it seeks to analyse adaptability and transformability.

Under a hypothetical threat, where fuel price increases or fossil fuels are depleted, new scenario(s) is (are) created. Under the new scenario(s), the goal is to evaluate how it can affect the aspects within the current conditions, in terms of social expenditure and available options (opportunities) in order to maintain (or persist) mobility patterns before the threat.

The post condition threat is a sub-stage of the persistence that will determine whether there is resiliency faced with fossil fuel dependency or an alternative to maintain mobility patterns. The next step is to evaluate the level of transformability, which is related to the willingness to create new mobility opportunities, based on the interest of social classes, transportation policies and planning and what is already in the process of implementation.

In case there is an alternative in the adaptability stage of analysis, it can be based on the same mobility patterns, but affecting current social conditions or it can be based on new mobility patterns, which is related to mobility opportunities already available. In the stage of adaptability, there are also factors that can influence the decision of an individual or social group to adapt, which are classified as current conditions of adaptability: the right to urban mobility, attractiveness, attitude, and origin and destination.

The conditions of adaptability can influence the alternatives of mobility and level of resilience. Although the meaning of each level of resilience has not yet been determined, the levels have been inserted to illustrate that high means a good level of resilience, and middle and low represent some level of vulnerability in urban mobility. In case there is a middle or low level, the next step is to evaluate the transformability.

The following sections are dedicated to building a solid methodological process regarding the presented resilience system. The methodological process is divided into three evaluation stages, persistence, adaptability and transformability, which are a mix of quantitative and qualitative methods.

6.1. Process of Contextualising Case Study

Before applying the steps of evaluation to the resilience of urban mobility, the city chosen for the case study is contextualised, based on elements of the urban mobility framework, presented in section 3.6.

Assuming that urban space is a product of social contradiction and conflicts, as reviewed in chapter 3, there are three elements, which spatially represent this logic: ideology of classes, economic and political-institutional.

The ideology of classes is understood as the nature of urban contradictions. These urban contradictions can be represented spatially, through the socio-spatial conditions and urban physical characteristics. As this thesis focusses on mobility, for contextualising the case study, the information that is used for the contextualisation of the ideology of classes, are the socioeconomic data spatialised and transportation infrastructure.

The economic elements regard the main economic activities of the city. For the contextualisation of this element, the data considered are the main economic activities and where they are located. Furthermore, geographical characteristics, such as the location of residential, industrial and commercial activities are also described.

The political-institutional is the third element, which is related to the location of the public institutions of the city. The focus is on gathering the location of public institutions that are related to urban and transport planning.

These three elements are the basis for the contextualisation of the case study. The next sections describe the methodological process of evaluation of the resilience of urban mobility, which was chosen based on the built theoretical framework, in chapter 3.

6.3. Evaluation of Persistence and Adaptability: Quantitative and Qualitative Approach

This section's objective is to present the proposed methodology to evaluate the stages of persistence and adaptability, based on the concept and framework of resilience of urban mobility.

The methodology consists of a quantitative and qualitative approach, which are described in the following sections.

6.3.1. Quantitative Approach

The intention of this section is to focus on a quantitative approach, based on the presented concept of resilience of urban mobility. Table 12 presents the data used in the proposed quantitative approach. The quantitative approach is limited to evaluating the stage of persistence and adaptability faced with a fossil fuel threat. It is observed that the attitude is an element of adaptability, which is not included in this model, because it is a qualitative aspect.

Table 12: Data Used on the Quantitative Approach of Resilience of Urban Mobility

Type of data	Description
Transportation system and infrastructure	Available public transportation and street network in the city (urban space).
Transportation costs	Fuel price and public transportation fare.
Wage	Parameters of highest and lowest wage in each neighbourhood (district) of the city and how many people are within each wage parameter.
Matrix of expenditure	Matrix of expenditure related to how much a person pays for transportation, education, health, food, leisure, clothes, housing, savings, etc.
Job positions	Number of job positions per neighbourhood (district) in the city.
Origin and destination	Information of the trip matrix of the sample.

The evaluation model is built on a conceptual approach of the production of urban space, based on intra-urban scale. The first step is to choose a city (case study) and then gather information on the transportation system and infrastructure. Getting information on the price for each transportation mode and understanding how this price varies with the distance travelled is also included in this step.

The second step is to gather data of wage parameters in each district of the city, along with gathering an approximate expenditure matrix for each wage level. The matrix of expenditure can be divided into four groups (a, b, c, d), where each group represents the expenses with different elements (Table 13).

Table 13: Elements in the groups of the matrix of expenditure

Matrix of Expenditure	Order of importance	Elements
a	1 (most important)	Housing; food; clothing; education; health
b	2 (important)	Leisure and others (e.g. superfluous consumption)
c	3 (less important)	Savings
d	4 (obligatory)	Transportation

The third step is to get information related to the number of job positions in each district, considering all sectors, such as agrarian, commercial, industry and services. This attribute represents the level of centrality of the district, in other words, it will weigh the importance of one district in relation to others.

After collecting the information, it is possible to apply the proposed methodology. Firstly, there is the order of importance of expenses, which can vary from one individual to another. However, for this thesis, we establish an order of importance of expenses based on the human security concept. Based on this perspective, the expenses on housing, food, clothing, education and health are the most important (Table 13), because they are the basic human needs. Therefore, these should be the last expenses to be sacrificed in a crisis scenario.

Based on the notion that only savings were to be affected, a person could maintain his/her living patterns, thereby establishing the savings as the less important expense. Through this conception, the savings would be the first expenses to be sacrificed in a crisis scenario. Therefore, expenses with leisure and others should be considered as second at the level of importance, because when this expenditure is affected there can be a certain change regarding the urban quality of life.

At last, it is understood that expenses with mobility are obligatory, because the circulation of people within the city is a determining factor for the functioning of the city. However, this does not mean that it is the most important element. One can have zero expenses on transportation, if the person lives in a certain condition, e.g. when one lives at a walking distance to work and to areas where there is an offer of commerce and services.

The proposed level of resilience regards the order of importance on the expenses. When the expenses with transportation affect only the savings (c) there is a high level of resilience, (b) there is a medium level of resilience when it affects leisure and others (a) there is a low level of resilience when it affects the basic needs.

Regarding the application of the quantitative method, firstly, one must calculate the expected and real costs. The expected cost is based on a matrix of expenditure (eq. 1, 2, 3 and 4), which can be gathered from fieldwork or from the local government. Secondly, one must calculate the real cost of transportation (eq. 5) based on the information on the transportation system of the city, seeking the cheapest way for each threat scenario. Thirdly, one must calculate the real cost of other expenditures based on the real cost of transportation and the order of importance of expenses, applying the equation in the following order: eq. 6, 7 and 8. It is important to understand that if the expected cost is equal to the real cost, then the necessary conditions to apply equations 6, 7 and 8 does not happen.

$$Ea = a \text{ x } W \quad (1)$$

$$Eb = b \text{ x } W \quad (2)$$

$$Ec = c \text{ x } W \quad (3)$$

$$Ed = d \text{ x } W \quad (4)$$

Where:

W: Wage (US$)
a, b, c, d: monthly expenses (%)
Ea, Eb, Ec, Ed: expected monthly expenses (US$)

$$Rd = Ed - PMij \quad (5)$$

Where:

Rd: Real monthly expenses with transportation (US$)
Ed: Expected monthly expenses with transportation (US$)
PM_{ij}: Price of Transportation (cheapest avalilable) to go from district i to j (US$)

$$if\ Rd < 0;\ Rc = Ec - (+Rd) \quad (6)$$

Where:

Rc: Real monthly savings (US$)
Rd: Real monthly expenses with transportation (US$)
Ec: Expected monthly savings (US$)

$$if\ Rc < 0;\ Rb = Eb - (+Rc) \quad (7)$$

Where:

Rc: Real monthly savings (US$)
Rb: Real monthly expenses with leisure and others (US$)
Eb: Expected monthly expenses with leisure and others (US$)

$$if\ Rb < 0;\ Ra = Ea - (+Rb) \quad (8)$$

Where:

Rb: Real monthly expenses with leisure and others (US$)
Ra: Real monthly expenses with basic needs (US$)
Ea: Expected monthly expenses with basic needs (US$)

After calculating the expected and real costs from the city, it will be possible to measure the resilience of one neighbourhood to another. This process includes transforming the results in 1 (one) or 0 (zero). If the real cost value is lower than the expected cost, then that expense will be 1 (one), and if it is equal or higher than the expected cost, then that expense will be 0 (zero). Table 14 is an example of the output of data. For each origin and destination, there can be different levels of resilience of urban mobility, because if the summing of the results of a column is between 0 and 2, it means high level of resilience, between 2 and 3 medium levels of resilience and between 3 and 4 low levels of resilience. This logic is based on the proposed order of importance of the expenses.

Table 14: Example of results of the proposed method

District of origin/destination	Matrix of expenses	j1	j2	j3
I	Ca*	0	0	0
	Cb*	0	0	1
	Cc*	0	1	1
	Cd*	0	1	1

*this means codification of expenses, for each group.

The last stage of the process is to calculate the resilience of each district in relation to the whole city. This part of the method is based on the first results, as shown in the example (Table 14) and the number of jobs available in each district in relation to the whole city.

$$RUMi = (\sum_{j}^{i}((Caij + Cbij + Ccij + Cdij) \text{ x } WJoj)) /100) \qquad (9)$$

Where:

RUMi: Resilience of urban mobility index for district i under the selected wage condition
Ca_{ij}: Codification of the basic needs expenses in 1 or 0, in between the district i (origin) and j (destination)
Cb_{ij}: Codification of leisure and other expenses in 1 or 0, in between the district i (origin) and j (destination)
Cc_{ij}: Codification of savings in 1 or 0, in between the district i (origin) and j (destination)
Cd_{ij}: Codification of transportation expenses in 1 or 0, in between the district i (origin) and j (destination)
WJo_{j}: level of job offers in the district of destination in relation to all other districts of the city based on the percentage of jobs for each district of the city (from 0 to 100).

Based on the example from Table 14 and eq. 9, Table 15 shows the procedure for the output results of the resilience of urban mobility from a district of origin in relation to the entire city, considering job position's level.

Table 15: Example of the output of the resilience measure of district i – considering job position's level

Origin/all destination	Variable	J1	J2	J3	Result
i	RUM	0	2	3	1.75

Obs: J1=25%; j2=50%; J3 = 25%

Naturally, for each district there is a possibility that they can contain a diversity of social groups with different wage conditions. It is proposed for this method to gather information of the quantity of people who are within different wage parameters. For each parameter, there will be a higher and lower income level, which can be referred, respectively, as optimistic (O) and pessimistic (P) scenarios. Table 16 shows the output of data, considering the wage parameters (W). After having this information, one should apply the weighted average based on how many from the sample are within each wage parameter.

$$RUMIij = ((\sum_{1,2,3\ldots}^{w}(W1,2,3,\ldots\ x\ RUMij)\ /100)) \qquad (10)$$

Where:
RUMIij: Final result of the resilience of urban mobility index
$W_{1,2,3,\ldots}$: Percentage of the total sample within each range of wage (0 to 100)
RUMij: Resilience of urban mobility index for district i under the selected wage condition

Based on the examples from Table 15 and eq. 10, Table 16 shows an example of the results of the resilience of urban mobility considering the wage parameters (ranges).

Table 16: Example of the output of the resilience measure considering wage parameters

Variable	O(W1)	O(W2)	O(W3)	P(W1)	P(W2)	P(W3)	RUMF (O)	RUMF (P)
RUMIij	1.75	2	3	2	3	4	2.05	2.6

OBS: W:Wage parameter; O: optimistic wage; P: pessimistic wage; W1=60%; W2=20%; W3=20%

To provide more clarity to the analysis, the index of the Resilience of Urban Mobility (RUMI) should be compared with the main variables used to produce the results, which are job data, wage, origin and destination (which can be translated as distance), accessibility to metro and/or train stations. This research proposes the generation of a vulnerability index based on the main variables that influence the results of the model. To calculate the vulnerability index, it is proposed to normalise the main variables commented earlier in this paragraph. This normalisation of data aims at converting the data to a range from 0 to 1, where 1 is the positive result and 0 is the negative result and it is negative in the sense of being the opposite of good. Table 17 presents the variables and description of the normalisation process. Furthermore, it also presents the means to calculate the vulnerability index.

Table 17: Variables for the vulnerability of urban mobility analysis

Variables	Description of standardization of data	Vulnerability Index Description
JobN	Eq. 11	Summing of JobN, WageN, DistanceN, MetroN and TrainN. The closest values to 5 mean low vulnerability and the closest values to 0 mean high vulnerability.
WageN	Eq. 12	
DistanceN	Eq. 13	
MetroN	If there is accessibility to a metro station, then 1, if not, then 0	
TrainN	If there is accessibility to a train station, then 1, if not, then 0	

$$JobNi = (Job_i – Min (from all Jobs))/(Max(from all Jobs) – Min(from all Jobs)) \quad (11)$$

Where:
JobNi: Normalised data of job positions of the district I (between 0 and 1)
Jobi: Percentage of job positions of the district i
Min (from all jobs):

$$WageNi = (LVWage * 1) \quad (12)$$

Where:
WageNi: Normalised wage conditions based on the quantity of people or households in the district i that has a less vulnerable wage condition (between 0 and 1)
LVWage: percentage of people or households with a less vulnerable wage condition

$$DistanceNi = 1- ((AWDi – Min (from all AWD)/(Max (from all AWD) – Min (from all AWD)) \quad (13)$$

Where:
DistanceNi: Normalise weighted average of distance of district i (between 0 and 1)
AWDi: Weighted averaged of distance based on job positions of district I
Min (from all AWD): Minimum value of the weighted average of distance of all districts of the city
Max (from all AWD): Maximum value of the weighted average of distance of all districts of the city

With the vulnerability index and the resilience of urban mobility index, it is possible to understand the reason for a district being more or less vulnerable faced with a fossil fuel threats. In addition to the discussion, it is important to note that the WageN variable should be based on the observation of the data of the city, where the researcher observes which salary ranges are considered the less vulnerable, based on the reality of the city.

The quantitative method to evaluate the resilience of urban mobility is described in this section. It is relevant to highlight that there can be different results depending on the transportation mode available and the socioeconomic conditions.

6.3.1.1. Statistical Evaluation of the Quantitative Approach

For a statistical evaluation, this research proposes the use of multiple linear regression model, which "estimates the coefficients of the linear equation, involving one or more independent variables, that best predict the value of the dependent variable" (IBM Corp., 2013). The different RUMI results, generated by different hypothetical price scenarios, are the dependent variables and the standardised data presented in Table 17 are the independent variables.

Before applying this statistical model, it is also suggested to standartise the RUMI results, following the logic that 0 is negative (referring to the level 4 of resilience of urban mobility index) and 1 is positive (level 0 of the resilience of urban mobility index). The standardisation process of RUMI is described in eq. 14.

$$RUMIN = 1 - (RUMIi /4) \qquad (14)$$

Where:
RUMIN: Normalised index of resilience of urban mobility (0 – 1)
RUMIi: Index of resilience of urban mobility of district i

This thesis proposes to use the software IBM SPSS (IBM Corp., 2013), which has a prompt multiple linear regression model. An example of the output of the results are located in Figure 54 and the results are described after this figure, based on the description of the Institute for Digital Research and Education of the University of California, Los Angeles (IDRE/UCLA, 2016).

Model Summary				
Model	R**(a)**	R Square**(b)**	Adjusted R Square **(c)**	Std. Error of the Estimate **(d)**
1	.939[a]	.882	.879	.021969177605284

a. Predictors: (Constant), DistanceN, TrainN, JobN, MetroN, WageN

ANOVA[a]						
Model		Sum of Squares **(e)**	df **(f)**	Mean Square **(g)**	F **(h)**	Sig.**(i)**
1	Regression	.558	5	.112	231.019	.000[b]
	Residual	.074	154	.000		
	Total	.632	159			

a. Dependent Variable: H1

b. Predictors: (Constant), DistanceN, TrainN, JobN, MetroN, WageN

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T **(n)**	Sig.**(o)**
		B **(j)**	Std. Error **(l)**	Beta **(m)**		
1	(Constant)	.463	.008		59.819	.000
	WageN	.260	.010	.821	26.877	.000
	MetroN	.003	.005	.017	.570	.569
	TrainN	-.002	.004	-.012	-.402	.689
	JobN	.104	.022	.139	4.839	.000
	DistanceN	.070	.009	.226	7.593	.000

a. Dependent Variable: H1

Figure 54: Output example of the multiple linear regression model – using IBM SPSS ver. 23

Where (IDRE/UCLA, 2016), based on Figure 54:

(a): *R is the square root of R-Squared and is the correlation between the observed and predicted values of dependent variable;*
(b): *R-Square – This is the proportion of variance in the dependent variable (science), which can be explained by the independent variables. This is an overall measure of the strength of association and does not reflect the extent to which any particular independent variable is associated with the dependent variable;*
(c): *This is an adjustment of the R-squared that penalises the addition of extraneous predictors to the model. Adjusted R-squared is computed using the formula 1 – ((1 – Rsq) ((N – 1)/ (N – k – 1)) where k is the number of predictors;*
(d): *This is also known as the root mean squared error. It is the standard deviation of the error term and the square root of the Mean Square for the Residuals in the ANOVA table.*
(e): *These are the Sum of Squares associated with the three sources of variance, Total, Model and Residual. The Total variance is partitioned into the variance, which can be explained by the*

independent variables (Regression), and the variance, which is not explained by the independent variables (Residual);
(f): *These are the degrees of freedom associated with the sources of variance. The total variance has N-1 degrees of freedom. The Regression degrees of freedom correspond to the number of coefficients estimated minus 1;*
(g): *These are the Mean Squares, the Sum of Squares divided by their respective DF;*
(h) and (i): *F and Sig. – This is the F-statistic the p-value associated with it. The F-statistic is the Mean Square (Regression) divided by the Mean Square (Residual). The p-value is compared to some alpha level in testing the null hypothesis that all of the model coefficients are 0;*
(j): *B – These are the values for the regression equation for predicting the dependent variable from the independent variable;*
(l): *Std. Error – These are the standard errors associated with the coefficients;*
(m): *Beta – These are the standardised coefficients. These coefficients could be obtained if all of the variables in the regression were standardised, including the dependent and all of the independent variables, and the regression was run. By standardising the variables before running the regression, all of the variables are put on the same scale, and the magnitude of the coefficients can be compared to see which one has more of an effect. The larger betas are associated with the larger t-values and lower p-values;*
(n) and (o): *t and Sig. – These are the t-statistics and their associated 2-tailed p-values used in testing whether a given coefficient is significantly different from zero, using an alpha of 0.05.*

The most important information of the model that will show the relationship between the variable are the adjusted R square (model summary), p-value from F (ANOVA table – labeled as Sig (j)), p-value from T (coefficients table – labelled as Sig. (o)) and the B value (coefficient table – labelled as B (j)).

The adjusted R square shows the proportion of the total variability of the dependent variables, which are explained by the independent variables. The p-value from F presents whether the null hypothesis is true or false. The null hypothesis is that the model has no explanatory power. However, if the p-value from F is equal or lower then 0.05, this means that the null hypothesis is false, in other words, the relationship between the dependent and independent variables makes sense. The p-value from T shows the significance of the influence of the independent over the dependent variables. If the p-value from T is equal or lower then 0.05, this means that the independent variable influences the dependent variable. The B value represents the level of influence of the independent variables over the dependent variable.

6.3.2. Qualitative Approach

This section defines the way to evaluate the qualitative aspects of persistence and adaptability. There are four elements of the adaptability stage in the resilience of urban mobility, which can be evaluated through a qualitative process: attractiveness; attitude; origin/destination and socioeconomic conditions.

It is understood that the human factor can affect the resilience of urban mobility, in terms of whether an individual or group would make the decision to be resilient or to sacrifice expenses and affect their resilience level. Due to the complexity, the condition of the city can possibly be leading one to avoid negative aspects of the city (air/noise pollution, urban violence, housing price, etc.), and to (maybe) spend more with transportation, to be distant from urban problems or less vulnerable.

To be more specific, the attractiveness has a certain affinity to the human needs in urban zones. To evaluate the attractiveness element, within the resilience of urban mobility, one must understand the level of affinity of an individual or group with the surroundings of his/her residential area, in other words, whether it is possible or not to find a job and undertake activities (e.g. shopping, hospital, schools, markets, etc.). A high level of attractiveness in the same or neighbourhood district from the residential area means that there are better conditions to adapt the mobility patterns and costs when faced with a fossil fuel crisis. Thus, it creates the opportunity for one to change origin and destination patterns in face of a crisis, and still maintains acceptable living conditions.

The attitude regards the possibility of one to change its mobility pattern in order to be less affected by fossil fuel crisis. There can be opportunities to change the mobility patterns, but it is understood that to adapt is a matter of choice. Furthermore, this choice can be based on personal view and ideology, and the socioeconomic conditions. For example, the choice for a specific transportation mode can be based on security notion, comfort, travel time, price, etc.

Initially, the qualitative approach to these elements includes taking interviews or sending questionnaires to private and public transportation users. Each city has its own particularities in terms of urban living and conditions. Therefore, it is relevant to build a questionnaire or interviews based on the mobility conditions and opportunities of the case study (city), in order to ask questions, which can be understood by the public and private transportation users.

Figure 56 presents the framework of the qualitative analysis of the resilience of urban mobility, focussing on the persistence and adaptability stage of analysis. Within this framework, it is possible to observe the analysis of the proposed elements. The frameworks also present the type of questions, which should be made.

Although the order of the questions in fieldwork should be adapted do ease the gathering of information, to present the method in a certain logic, the framework is discussed following the analysis order, not necessarily the order of the information gathered in fieldwork.

Before, initiating the discussion on the framework, it is important to have all sample organised. Figure 55 presents how data should be organised. After tabulating all data in a databank software, such as Excel, a filter to the data is applied. Therefore, after applying questionnaires and tabulating data, firstly, the applied filter focusses on selecting the trips that are within the same city. The second filter is working trips. The reason for selecting working trips is because, firstly, it is the motive that generates a large part of the movement in the city, and secondly, because those who are moving for working reasons, generally, has a higher probability of knowing about their expenses, in relation to what it is earned with the salary.

The next step is creating three groups with the selected sample. These groups of data are as follows: private transportation users, public transportation users and both, private and public transportation users. The private transportation users' group represents those who only use private transportation. For public transportation, it is the same logic. The last one is the group of people who affirm that they use both private and public transportation. After having this data organised as proposed, it is possible to start the analysis process.

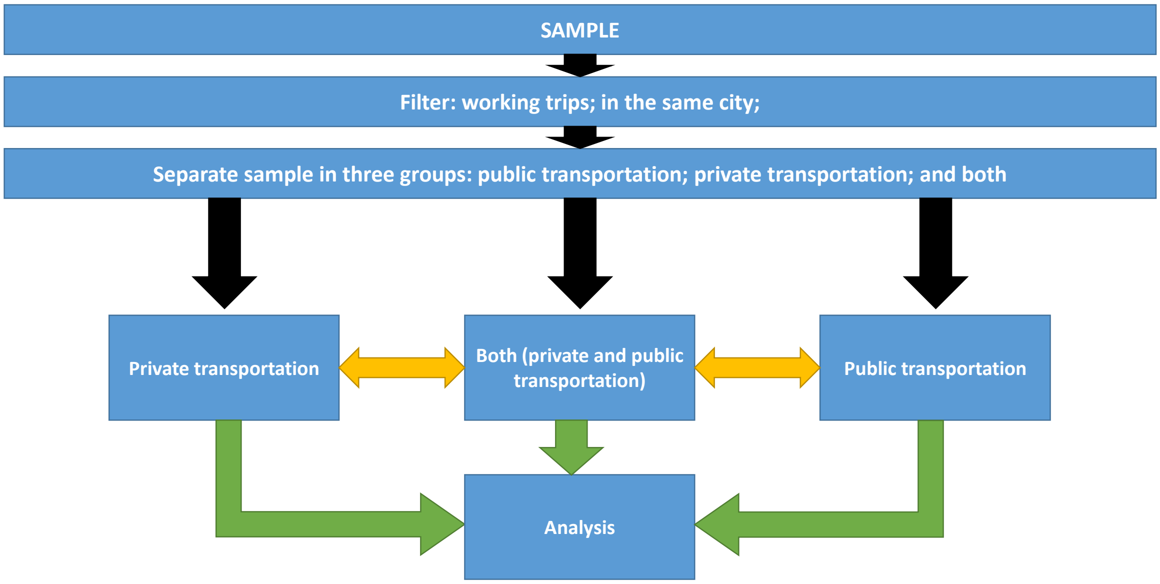


Figure 55: Pre-analysis stage

The reason why it is interesting to create these three proposed groups is the possibility to understand the trends of how these groups will react during a fossil fuel crisis. Those that already use both public and private transportation can possibly be considered the ones that are more flexible in adapting and changing to better choices when facing a sudden threat. While those that use only private or public can be more limited, each with their own reasons, which explores the data analysis stage of the research.

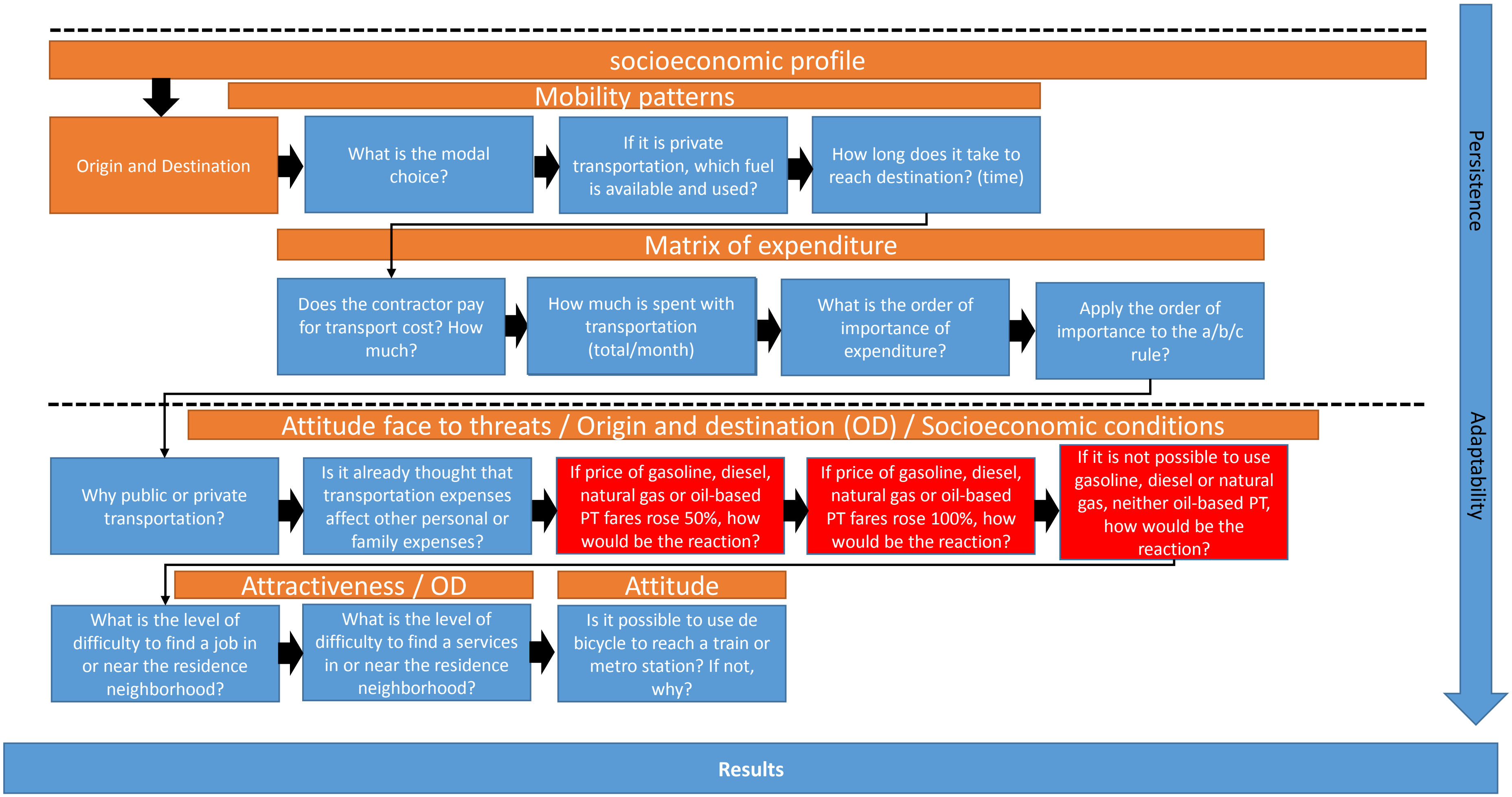


Figure 56: Framework for qualitative analysis of the resilience of urban mobility – focus on the persistence and adaptability stage – under the perspective of the user of transportation systems

As shown in Figure 56, the analysis of data in the adaptability and persistence stage is composed of a logical path based on the conceptual framework of resilience of urban mobility. Firstly, the socioeconomic information is compared and analysed, based on the three groups, divided previously. The socioeconomic data involves the following variables: gender, wage, level of education and the formality of the job (whether it is formal or informal).

The next step is to analyse origin and destination of the sample from the three proposed groups, and further analyse the data related to mobility patterns, involving modal choice, most used fuel for private transportation and how long it takes to reach the destination. Then there are the analyses of the matrix of expenditure, evaluating whether people receive the benefit of transportation cost by the contractor and how much this benefit is. Furthermore, it is analysed how much is spent on transportation, then the order of importance of expenditure based on the three groups of expenditure, beside the transportation costs. Based on importance, the a/b/c rule is applied to each individual, which is the adaptation of the order of importance based on the sample, under the notion that "a" is the most important and "c" is the less important.

These first analyses create the conditions to evaluate the level of persistence stage of the resilience analysis. This means understanding whether the current conditions of mobility pattern and socioeconomic conditions can be maintained or are favourable when facing a possible fossil fuel crisis.

After analysing the persistence stage, the adaptability stage is analysed, involving the elements of attitude, origin and destination, attractiveness and socioeconomic conditions. First, part of this analysis is to understand the reason why one chooses private over public transportation, or the other way around, and why one would choose both. Then, it is analysed whether it is thought that the transportation expenses already affect personal or family expenses. These two points to be analysed involves the elements of attitude and socioeconomic conditions.

Following this, the hypothetical scenarios are taken into consideration, where the users of private and public transportation are exposed to questions related to how they would react when faced with possible fossil fuel threats. Three hypothetical crisis scenarios are put forth: increase of 50% of gasoline, diesel, natural gas and fares of oil-based public transportation; 100% of the same source and a scenario without fossil fuels and oil-based public transportation.

Hereafter, attractiveness and attitude are analysed, considering whether each of the groups show some level of difficulty to find jobs and services in the same or neighbourhood district from residence. Another factor is whether people think it is possible to cycle to a nearby train or metro station.

Now that the process is described, it is important to point out how the data will be represented, in order to clarify the analysis and to ease the identification of the most influential responses.

The three ways in which the data of questionnaires can be represented are absolute number, percentage and data coding. These are used in the evaluation process, each type for the suitable element and analysis (Table 18). The absolute number is used to describe the total sample size and divides sample size from each group of data.

Table 18: Types of measures for each data set within the elements evaluated of the persistence and adaptability stage

Data	Measures
Socioeconomic data	Percentage
Attitude data	Percentage and data coding
Origin and destination	Percentage
Attractiveness	Percentage
Mobility patterns	Percentage

For the other types of data representation, the percentage output is used to describe and analyse socioeconomic data, origin and destination, attractiveness and mobility pattern. For the data related to attitude, percentage and data coding as output measures are present.

The first two presented output representations are quite simple, absolute number or percentage of data. However, the coding process is an interpretative process, which is explained later on. As all elements involve a large amount of questions, for the ones related to attitude, the suggested approach is to build a question that the respondent has to agree to or not have certain affirmations.

The amount of responses for one or more affirmation allows the calculation of the percentage of responses in relation to the sample, aiming on five levels of answers, which are described in Table 19. Consequently, certain responses from this process are highlighted, leading to a coding of interpretation based on the set of answers.

Table 19: Coding process of qualitative data

Responses in relation to the sample	Code	Interpretation coding
75%<response≤100%	4	Based on the answers, an interpretation coding is generated.
50%<response≤75%	3	
25%<response≤50%	2	
0%<responses≤25%	1	
0%	0	

Another step of the qualitative approach for the analysis of persistence and adaptability is from the researcher and professionals. This approach involves an interpretative analysis in two ways to build questionnaires. One is the open-ended questionnaire and the other is multiple-choice. They have different approaches of analysis. The first is more related to an interpretative analysis, while the second is associated to a descriptive approach, leading to a descriptive statistics perspective.

6.4. Evaluation of Transformability: Qualitative Approach

This section is dedicated to present the proposed evaluation of the transformability stage in the resilience of urban mobility. There are seven elements within the transformability stage: social movements; public transportation; attractiveness; built environment; the right to urban mobility; attitude and public and private sector.

This approach is based on the understanding of the interest of different agents responsible for improving and changing the urban mobility. The evaluation of transformability has a qualitative approach, which is based on interviews, questionnaires, documents’ analysis (policies, reports, papers, newspapers, etc.). It is important to highlight that each of the elements in this stage has subtopics related, which increases the complexity of the analysis.

The social movement’s element is related to social movements with the collective consumption goal, which are interested in changing policies that improve the urban mobility, based on their interests, values and needs, consequently allowing a change in the urban and mobility meaning. To gather information related to this element, it is relevant to understand the social movement itself, and how people think about social movements, whether they think it as important or not and if they participate somehow. Another perspective of social movements is from those who are responsible for planning and implementing mobility and transportation solution in the city, such as researchers, decision makers, professionals in the field, etc.

The elements of attractiveness and built environment can be analysed together, because both are related to urban space, in terms of land use distribution and organisation. These elements seek to find the interest of different agents on restructuring the city in order to offer a fair accessibility to jobs, commerce and services, etc. from a geographical perspective.

The right to urban mobility is related to the transport and mobility planning. The question is how inclusive are the transport and mobility planning of the city? Whether the professionals related to the planning process have any interest in including the citizens into the process and if they want to implement solutions that bring real benefits for a long term period.

Attitude is an element, which can also be understood as ideology. This element regards how transportation and mobility planners think about the planning process. The literature available on transportation planning points out the elements that can be considered as good practice. Through the comprehension of good practice (from literature) and real practice (on the case study), there can be an understanding whether the decision makers and planners are leading the city towards a resilient or non-resilient direction.

The public and private sector play an important role in stimulating different mobility patterns. The public sector can offer subsidy for the transportation sector and the private sector can offer transportation benefits through extra salary for transportation expenses or even offering executive transportation for the employees. Generally, the qualitative evaluation of these elements aim to analyse how these sectors contribute in increasing or decreasing the resilience of urban mobility in case of future possible crises.

CHAPTER 7

7. REASONING AND CONTEXTUALISING CASE STUDY: RIO DE JANEIRO – RJ/BRAZIL

Rio de Janeiro is a city that, for long time, has been experiencing a mobility crisis (Costa, da Silva, & Cohen, 2013). Since the 1950s in Brazil, there have been increasing use of buses and automobiles, and until recently, the rail system has been diminished (Costa, da Silva, & Cohen, 2013).

Table 20 provides information on the average daily trips by each transportation mode in the Metropolitan Region of Rio de Janeiro in 2012. Looking this information, it is possible to observe that around 61% of all daily trips in this region are based on fossil fuels. Thus, one can question the level of resilience of urban mobility in Rio de Janeiro when faced with fossil fuel dependency.

Table 20: Average daily trips by transportation mode in the Metropolitan Region of Rio de Janeiro in 2012 (Governo do Rio de Janeiro, 2013)

Mode	Daily Trips (1000)	Percentual
Automobile (driver)	2,540	11.24%
Automobile (passenger)	1,225	5.42%
Bicycle / Ciclomotor	546	2.42%
Bus (executive)	70	0.31%
Bus (illegal)	16	0.07%
Bus (intermunicipal)	1,781	7.88%
Bus (Municipal)	6,671	29.52%
Chartered transportation	55	0.24%
Ferrie	105	0.46%
Metro	665	2.94%
Motorcycle	170	0.75%
Moto-Taxi	39	0.17%
Others	169	0.75%
School transportation	428	1.89%
Taxi	256	1.13%
Train	568	2.51%
Van	658	2.91%
Walking	6,634	29.36%
Total	22,596	100.00%

The following subsections are aimed at contextualising the city of Rio de Janeiro, based on the suggested methodological process. This section gives a geographical perspective of the elements, which represent the general view of the logic of production in the urban space, in the case of Rio de Janeiro.

7.1. Ideology of Classes: Spatial Distribution of Socioeconomic Conditions and Transportation Infrastructure

The total population count of Rio de Janeiro is 5,560,655 (IBGE, 2010). The entire state is estimated at 15,989,929 (IBGE, 2010). This section shows the spatial distribution of the population count in the city in Figure 57. It is followed by Table 21, which presents the names of the neighbourhoods related to each code in Figure 57.

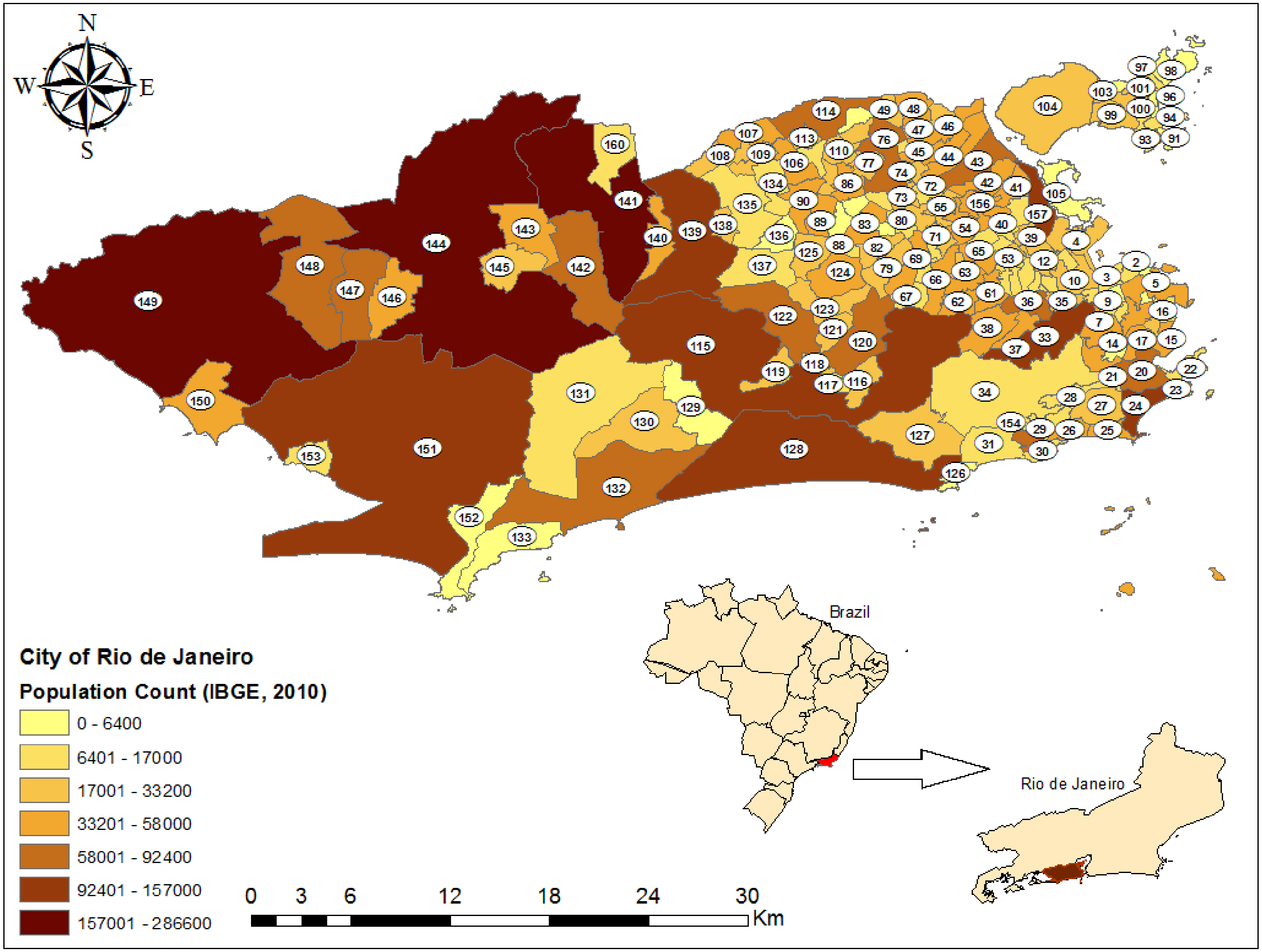


Figure 57: Population count of each neighbourhood of the city of Rio de Janeiro (IBGE, 2010)

Table 21: Name of the neighbourhoods based on the code of Figure 57

Neighborhood Name	Code	Neighborhood Name	Code	Neighborhood Name	Code	Neighborhood Name	Code
Saúde	1	Olaria	42	Cascadura	82	Taquara	122
Gamboa	2	Penha	43	Madureira	83	Tanque	123
Santo Cristo	3	Penha Circular	44	Vaz Lobo	84	Praça Seca	124
Caju	4	Brás de Pina	45	Turiaçú	85	Vila Valqueire	125
Centro	5	Cordovil	46	Rocha Miranda	86	Joá	126
Catumbi	6	Parada de Lucas	47	Honório Gurgel	87	Itanhangá	127
Rio Comprido	7	Vigário Geral	48	Osvaldo Cruz	88	Barra da Tijuca	128
Cidade Nova	8	Jardim América	49	Bento Ribeiro	89	Camorim	129
Estácio	9	Higienópolis	50	Marechal Hermes	90	Vargem Pequena	130
São Cristóvão	10	Jacaré	51	Ribeira	91	Vargem Grande	131
Mangueira	11	Maria da Graça	52	Zumbi	92	Recreio dos Bandeirantes	132
Benfica	12	Del Castilho	53	Cacuia	93	Grumari	133
Santa Teresa	14	Inhaúma	54	Pitangueiras	94	Deodoro	134
Flamengo	15	Engenho da Rainha	55	Praia da Bandeira	95	Vila Militar	135
Glória	16	Tomás Coelho	56	Cocotá	96	Campo dos Afonsos	136
Laranjeiras	17	São Francisco Xavier	57	Bancários	97	Jardim Sulacap	137
Catete	18	Rocha	58	Freguesia (Ilha)	98	Magalhães Bastos	138
Cosme Velho	19	Riachuelo	59	Jardim Guanabara	99	Realengo	139
Botafogo	20	Sampaio	60	Jardim Carioca	100	Padre Miguel	140
Humaitá	21	Engenho Novo	61	Tauá	101	Bangu	141
Urca	22	Lins de Vasconcelos	62	Moneró	102	Senador Camará	142
Leme	23	Méier	63	Portuguesa	103	Santíssimo	143
Copacabana	24	Todos os Santos	64	Galeão	104	Campo Grande	144
Ipanema	25	Cachambi	65	Cidade Universitária	105	Senador Vasconcelos	145
Leblon	26	Engenho de Dentro	66	Guadalupe	106	Inhoaíba	146
Lagoa	27	Água Santa	67	Anchieta	107	Cosmos	147
Jardim Botânico	28	Encantado	68	Parque Anchieta	108	Paciência	148
Gávea	29	Piedade	69	Ricardo de Albuquerque	109	Santa Cruz	149
Vidigal	30	Abolição	70	Coelho Neto	110	Sepetiba	150
São Conrado	31	Pilares	71	Acari	111	Guaratiba	151
Praça da Bandeira	32	Vila Kosmos	72	Barros Filho	112	Barra de Guaratiba	152
Tijuca	33	Vicente de Carvalho	73	Costa Barros	113	Pedra de Guaratiba	153
Alto da Boa Vista	34	Vila da Penha	74	Pavuna	114	Rocinha	154
Maracanã	35	Vista Alegre	75	Jacarepaguá	115	Jacarezinho	155
Vila Isabel	36	Irajá	76	Anil	116	Complexo do Alemão	156
Andaraí	37	Colégio	77	Gardênia Azul	117	Maré	157
Grajaú	38	Campinho	78	Cidade de Deus	118	Parque Colúmbia	158
Manguinhos	39	Quintino Bocaiúva	79	Curicica	119	Vasco da Gama	159
Bonsucesso	40	Cavalcanti	80	Freguesia (Jacarepaguá)	120	Gericinó	160
Ramos	41	Engenheiro Leal	81	Pechincha	121	Lapa	161

Based on Figure 57, it is possible to observe that the neighbourhoods located in the west and middle parts of the city are more populated. It is noticed that these areas are located in the neighbourhoods with bigger area (in square meters), in exception to those that are located in mountainous planes, as we can see in Figure 58. These ones are not as populated as the others are due to relief issues.

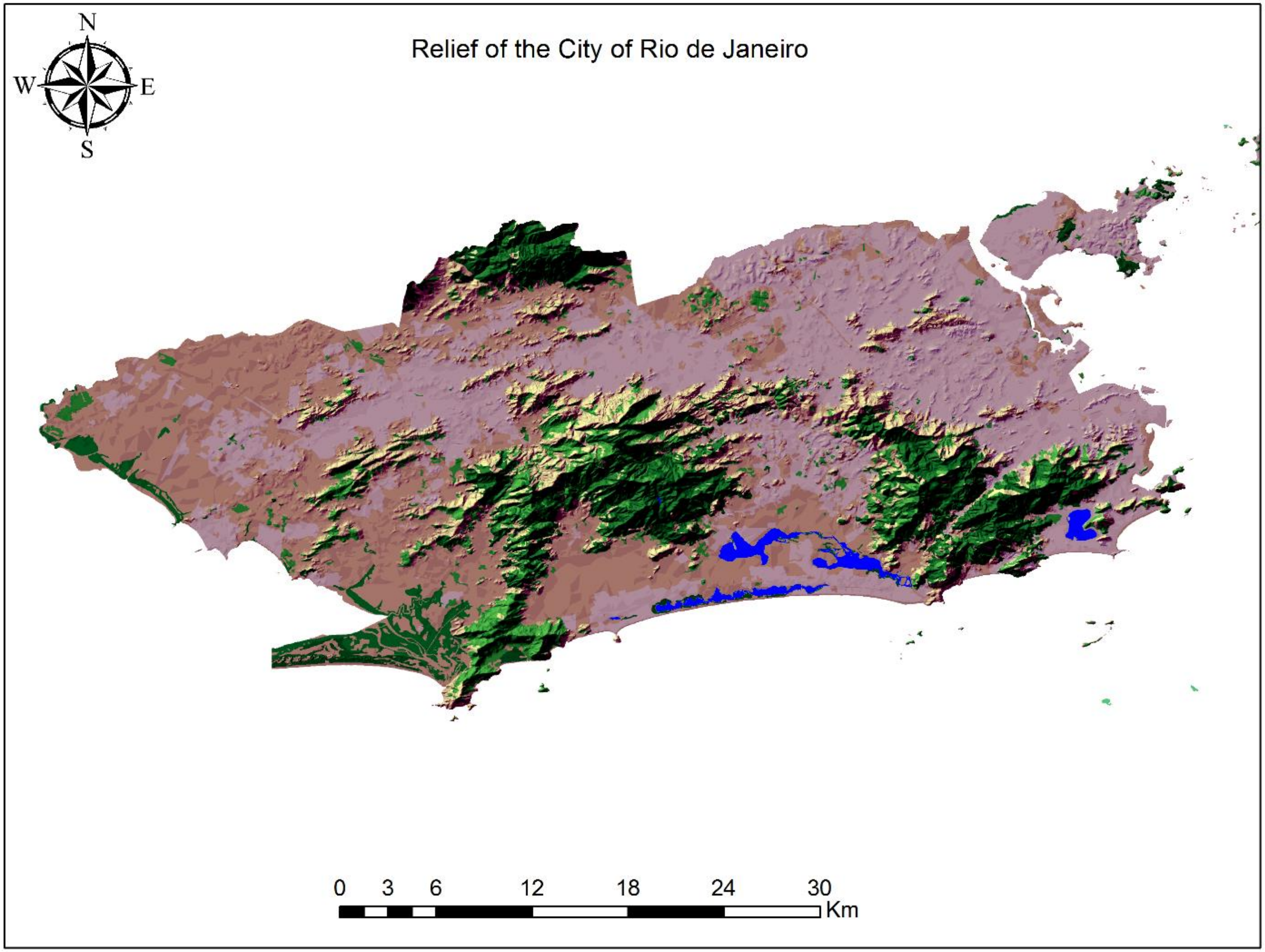


Figure 58: Relief of the City of Rio de Janeiro (Instituto Pereira Passos, 2015)

Figure 59 shows the location of the *favelas* ("slums") of Rio de Janeiro. Before describing the geographical distribution, it is important to know the definition of *favelas*, as described by the Brazilian Institute for Geography and Statistics (IBGE).

Favelas are characterised by a group of, at least, 51 dwelling units (houses, shacks, etc.) lacking, mostly, in essential public services. Furthermore, they occupy or have occupied, until the present day, a private or public land, in a disorderly form, in terms of space and infrastructure (IBGE, 2010).

It is observed that most *favelas* are located in east side of the city (Figure 59), in places where per capita income is low, as shown in Figure 60. It is also relevant to highlight that the middle and east part of the city concentrates the majority of job positions (Junior & Junior, 2010), especially *Centro* and *Barra da Tijuca* (Figure 57;Table 21).

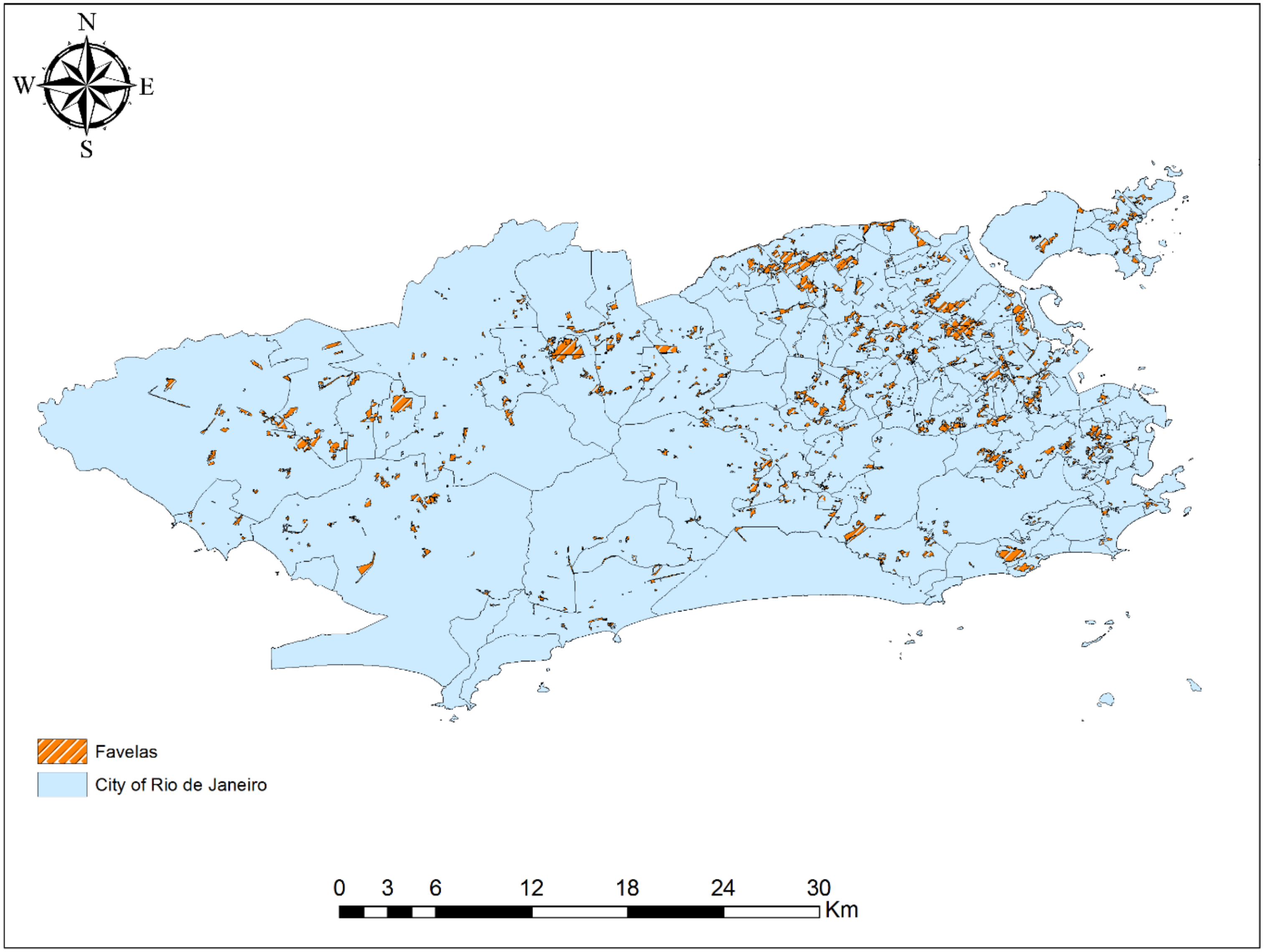


Figure 59: Location of the Favelas in the City of Rio de Janeiro (Instituto Pereira Passos, 2015)

Figure 60 show the average per capita income in each neighbourhood of the city of Rio de Janeiro. Different from the population count information, the higher average income is concentrated in the south coast of the city. The next step is to understand in which transportation context this socio-spatial information is situated.

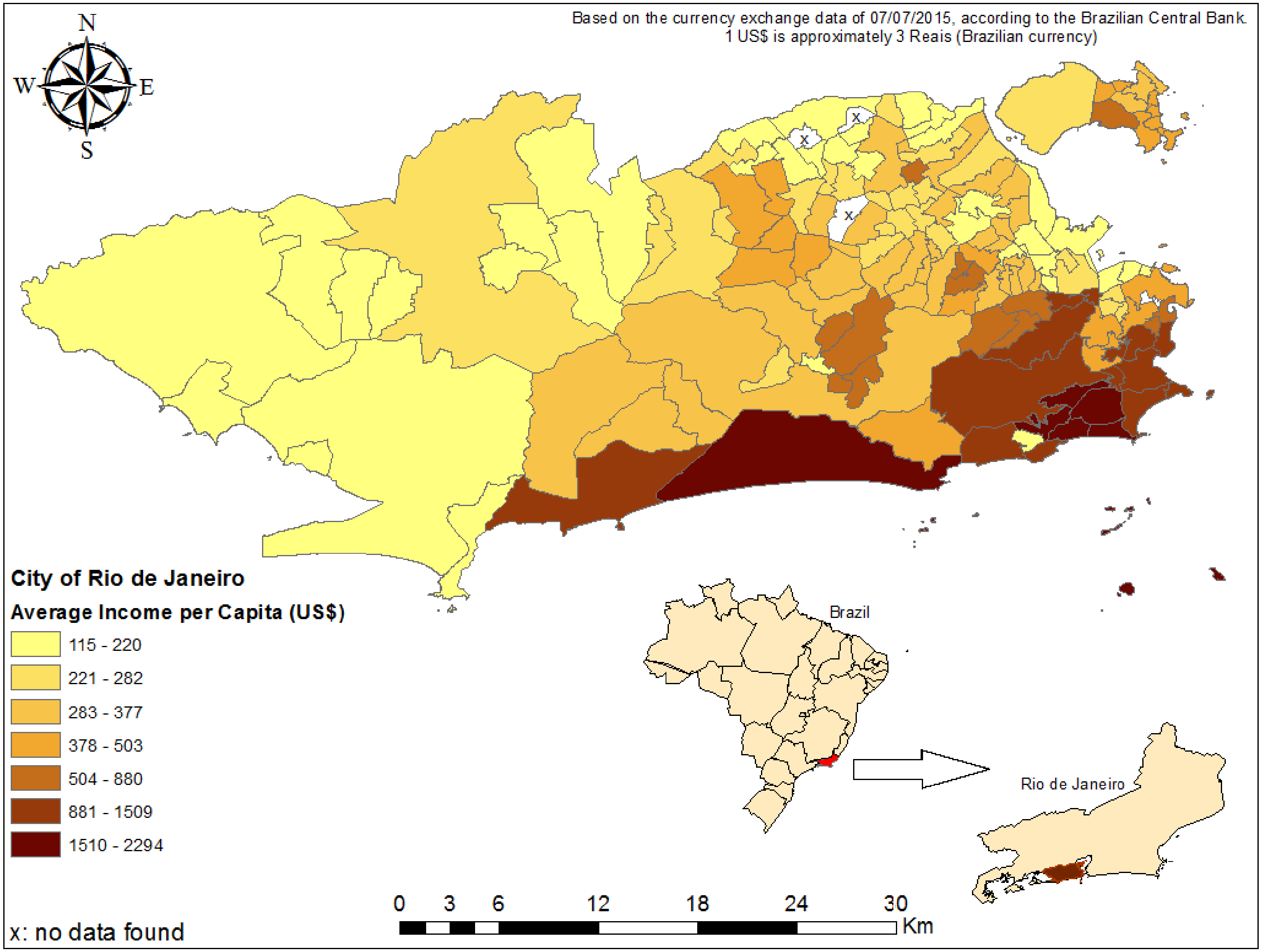


Figure 60: Average Per Capita Income in the city of Rio de Janeiro (IBGE, 2010)

Figure 61 presents the transportation system and structure of the city of Rio de Janeiro. It is observed, generally, that there are different available modes within the city, but accessible at different scales. The four main transport modes intercede in the northeast part of the city. In this area, there are the urban trains, metros, BRT (Bus Rapid Transit) and urban buses. In the case of the last one (buses), they are available all around the city. Logically, there is better accessibility to buses and private car trips (for those who have a car), judging by the density of streets and bus stops.

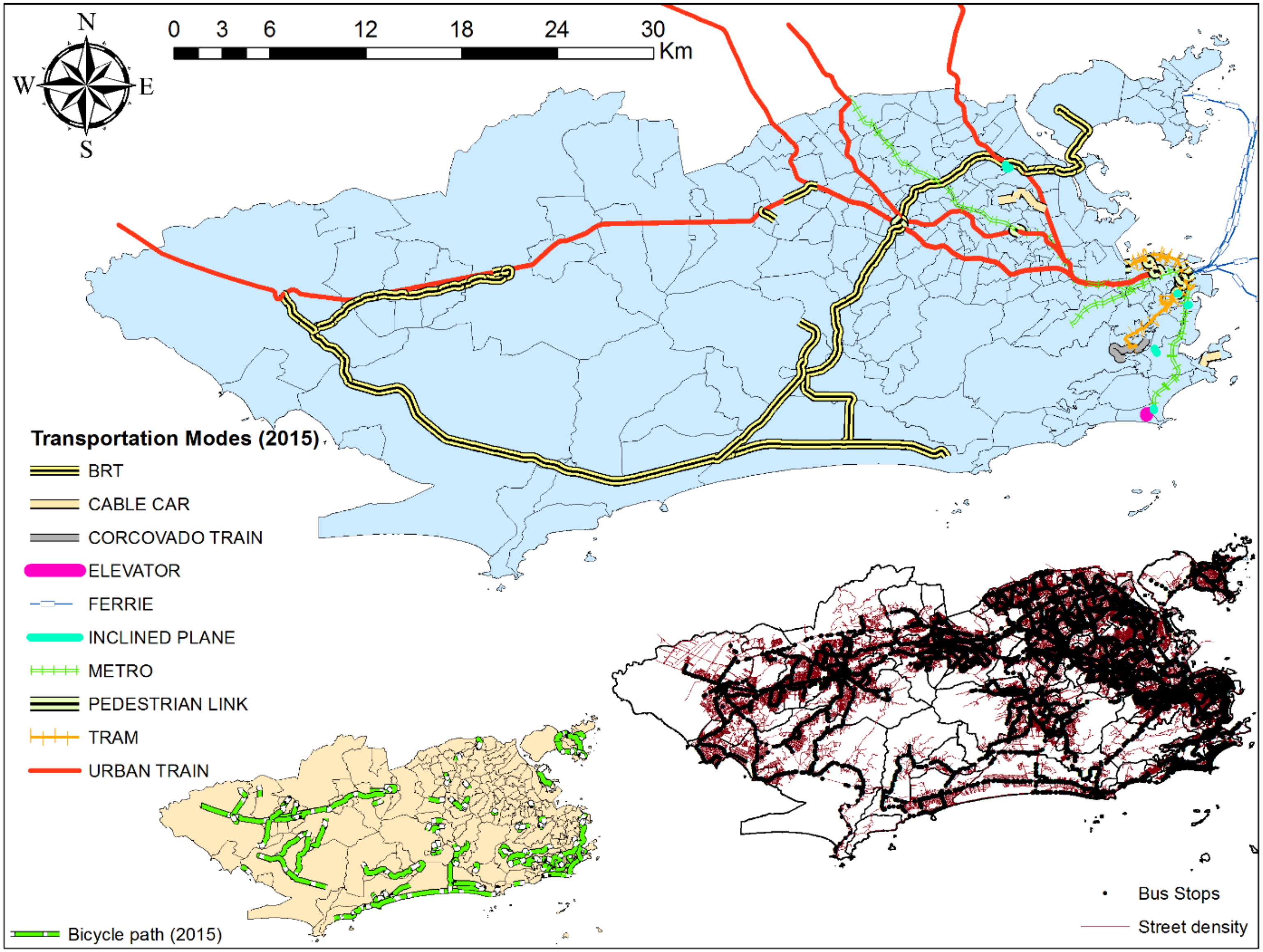


Figure 61: Transportation System and Structure in the City of Rio de Janeiro (MobiRio, 2014; Prefeitura do Rio de Janeiro, 2015)

Geographically, the urban trains are oriented to neighbourhoods with lower average income, while BRT and metros attend mostly the neighbourhoods with a middle- and high-income level. It is also possible to observe the topography factor (Figure 58), which influences the design of the transportation system. Although, from a flat perspective, some places seem near to each other, there are the relief characteristics, which can increase the distance between two places. This topography issue, for instance, can influence the connection of bicycle paths. As shown in Figure 61, the bicycle paths are not connected and there is low presence in the northeast part of the city.

7.2. Economic Characteristics and Political-Institutional Distribution

This section aims to describe the economic characteristics and activity distribution in the city of Rio de Janeiro. It is observed in Figure 62 that the main sector in Rio de Janeiro is commerce and services. Commerce and services sector is the one that generates adequate job positions, not only in Rio de Janeiro, but also in the entire southeast region of Brazil (BRASIL, 2009).

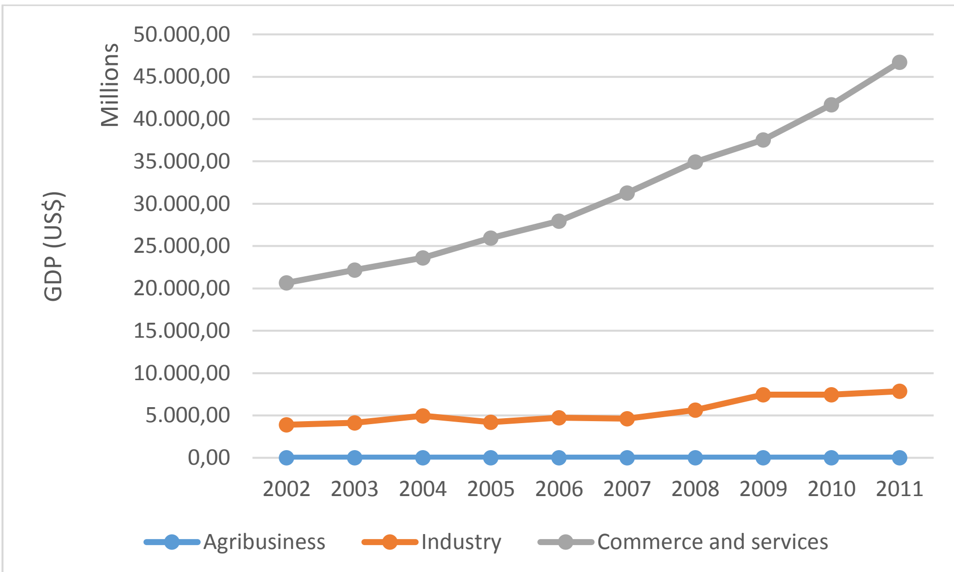


Figure 62: GDP by Sector of the City of Rio de Janeiro (Prefeitura do Rio de Janeiro, 2014)

Figure 63 presents the distribution of activities and land use in the city of Rio de Janeiro. Firstly, it is possible to observe that the residential areas are distributed in all parts of the city. However, the public infrastructure and institutes are present in the north and east part of the city. The slums are spatially present throughout the city, but lesser along the coast. Service and commerce are present in all parts of the city, but with a higher concentration in the north east, east and southern part. Furthermore, the leisure areas of the city are, visibly, more apparent in the southern and eastern part.

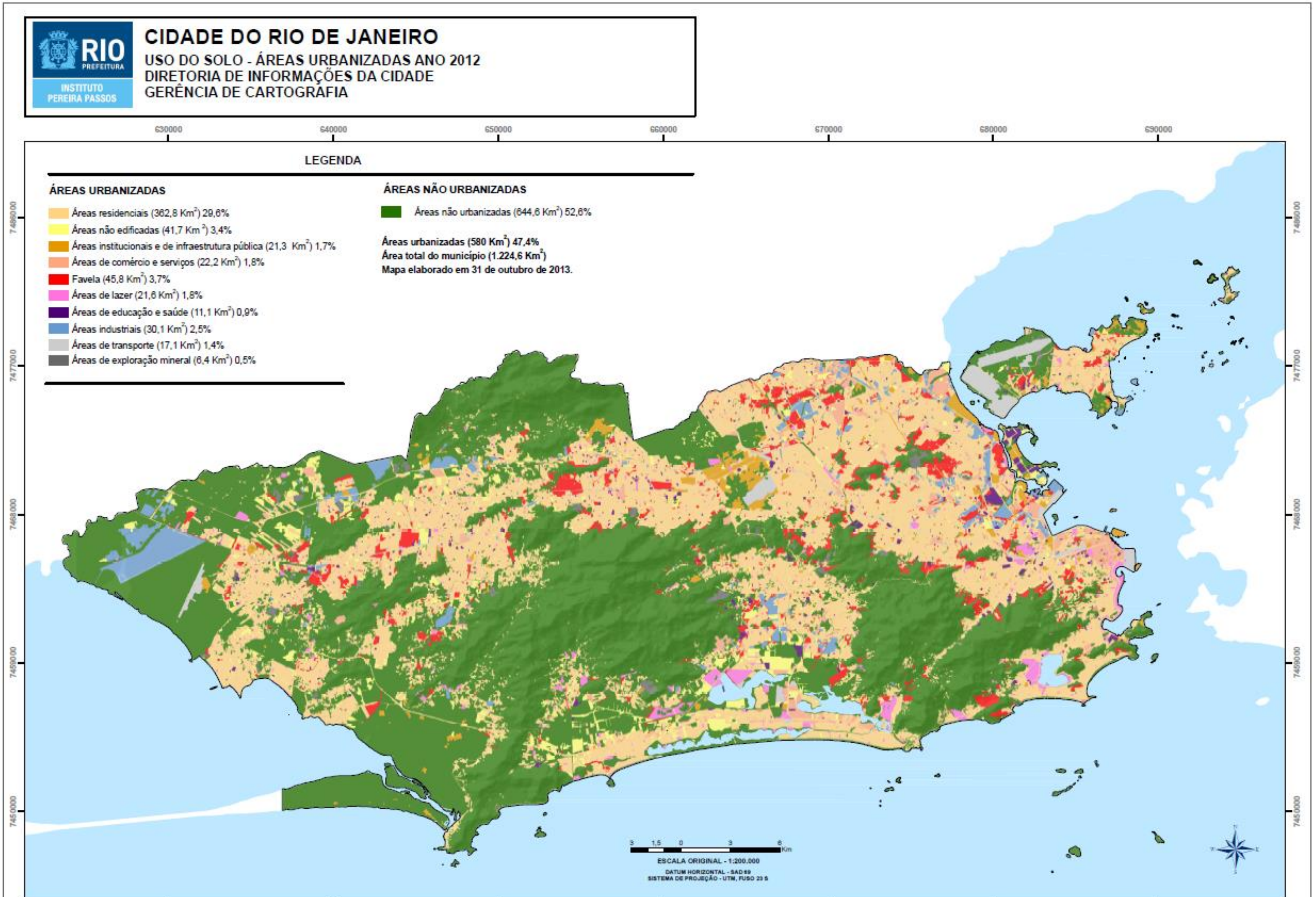


Figure 63: Land Use Distribution in the City of Rio de Janeiro (Prefeitura do Rio de Janeiro, 2014)

Table 22: Translation of Legends in Figure 63

Legend in Portuguese	Legend in English
Área Urbanizada	Urbanised Area
Área Residenciais	Residential Area
Área nao edificada	Not Built Area
Áreas institucionais e de infraestrutura publica	Areas of public institutes and infrastructure
Área de comércio e servicos	Commerce and service areas
Favelas	Slums
Areas de Lazer	Leisure areas
Áreas de educacao e saude	Education and health area
Áreas industriais	Industrial Area
Área de transportes	Transportation Area
Áreas de exploracao mineral	Mineral exploration area

Figure *64* is representation of the characteristics of the city in terms of development needs, based on four types of "macrozones of occupation", which is the term used in the development plan of the municipality of Rio de Janeiro (Prefeitura do Rio de Janeiro, 2011). The description of the macrozones of occupation is based on Rio de Janeiro's report, described in the following points (Prefeitura do Rio de Janeiro, 2011):

- Urban macrozone of assisted occupation – where the population density, the increase of economic activities and the installation of economic complex should be accompanied by public investment in infrastructure and measures to protect the environment and agriculture;

- Urban macrozone of conditioned occupation – where the population density, the intensity constructive and installation of economic activities will be restricted according to the capacity of the network infrastructure and subjected to the environmental and landscape protection, and can be progressively extended to the investment of private resources;

- Urban macrozone of controlled occupation – where the population density, constructive intensity will be limited, urban renewal will occur preferably for reconstruction or the conversion of existing buildings and the growth of trade and services activities in places where the infrastructure is sufficient, subjected to the predominant residential areas;

- Urban macrozone of promoted occupation – where the population density, constructive intensity and the increase of economic activities and large equipment will be encouraged, preferably in areas with higher availability or potential infrastructure deployment.

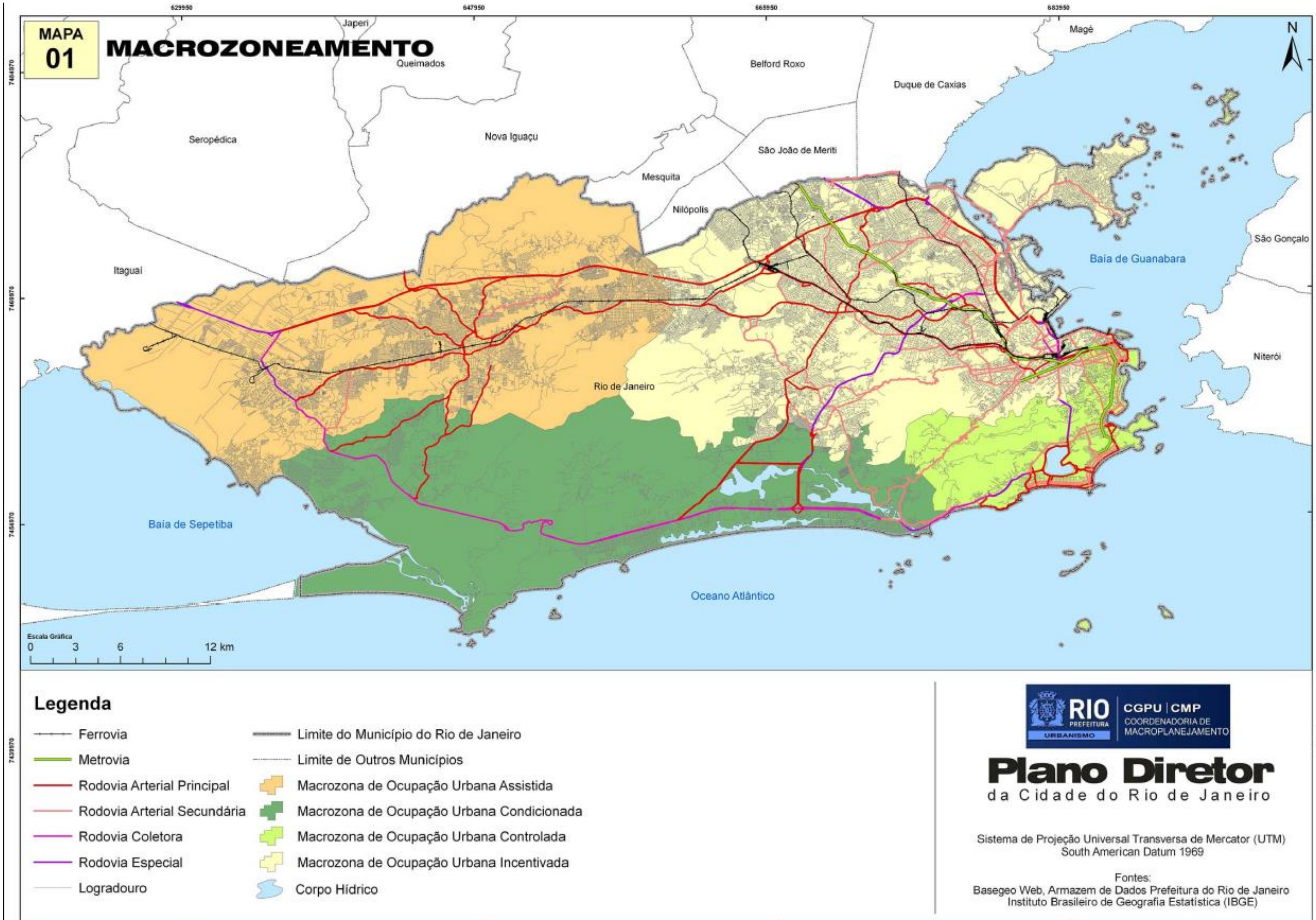


Figure 64: Macrozones of the City of Rio de Janeiro – According to the Development Plan Report of the City (Prefeitura do Rio de Janeiro, 2014)

Table 23: Translation of Legends in Figure 64

Legend in Portuguese	**Legend in English**
Ferrovias	Train
Metrovias	Metro
Rodovia arterial principal	Primary arterial highway
Rodovia arterial secundária	Secondary arterial highway
Rodovia coletora	Collector highway
Rodovia especial	Special highway
Logradouro	Street
Limite do município do Rio de Janeiro	Municipal boundary of Rio de Janeiro
Limite de outros municípios	Limit other municipalities
Macrozona de ocupação urbana assistida	Urban macrozone of assisted occupation
Macrozona de ocupação urbana condicionada	Urban macrozone of conditioned occupation
Macrozona de ocupação urbana controlada	Urban macrozone of controlled occupation
Macrozona de ocupação urbana incentivada	Urban macrozone of promoted occupation
Corpo hídrico	Water body

According to the macrozone's classification presented above, the government of the city of Rio de Janeiro highlights that the urban macrozones of assisted and promoted occupations are the ones that require more attention, concerning public investments, due to the lack of economic activities and infrastructure that can benefit the citizens who reside in these areas. These areas are composed of districts with less than average salaries and job positions regarding the other two macrozones.

CHAPTER 8

8. RESULTS: CASE STUDY

This chapter shows the results based on the proposed analysis process in the resilience of urban mobility in the city of Rio de Janeiro.

8.1. Variables Applied to the Case Study: Rio de Janeiro

This section aims to present all variables collected to apply the methodology of evaluation of the resilience of urban mobility in Rio de Janeiro. There are two approaches to this study case, qualitative and quantitative.

The quantitative analysis is based on the data found in official websites from the governments of the city of Rio de Janeiro and data from the national scale (Federal Republic of Brazil), respectively, municipal and national scale. The qualitative approach involves two main perspectives, firstly, the private and public transportations users and secondly, the researchers and professionals' perspective.

Getting into the sample issue, a survey was applied during a fieldwork at the city of Rio de Janeiro. Through an online and street survey, 1728 responses were collected. However, not all data was considered for the case study analysis. According to the conceptualisation of the resilience of urban mobility and framework of this concept, there is a need to filter the data. In the section 6.3.2 regarding the qualitative methodology, a filtering process is proposed. Therefore, through the application of the filtering process, considering certain criteria, the sample size was reduced to 369, as presented in Table 24. Furthermore, this table presents the sample size for each proposed group of data.

Table 24: Sample size from the survey in the city of Rio de Janeiro

Sample groups	Sample size	%
Private transportation	45	12%
Public transportation	253	69%
Both types	71	19%
Total	369	100%

8.2. Persistence, Adaptability and Transformability Variables

As explained earlier in this chapter, for the persistence and adaptability evaluation, there is a quantitative and qualitative approach. Therefore, didactically, the variables are described in this section.

Rio de Janeiro consists of 160 districts, which accounts for1224.4 Km^2, with approximately six million residents. A city of this proportion, along with the variety of social and infrastructural conditions distributed along the city, brings a certain complexity to the urban mobility analysis. Therefore, for the quantitative and qualitative analysis, the city will be evaluated based on nine macrozones, established by the transportation report of the government of Rio de Janeiro, called the Development Plan for Urban Transport in the Metropolitan Region of Rio de Janeiro, presented in Figure 65 (Governo do Estado do Rio de Janeiro, 2010).

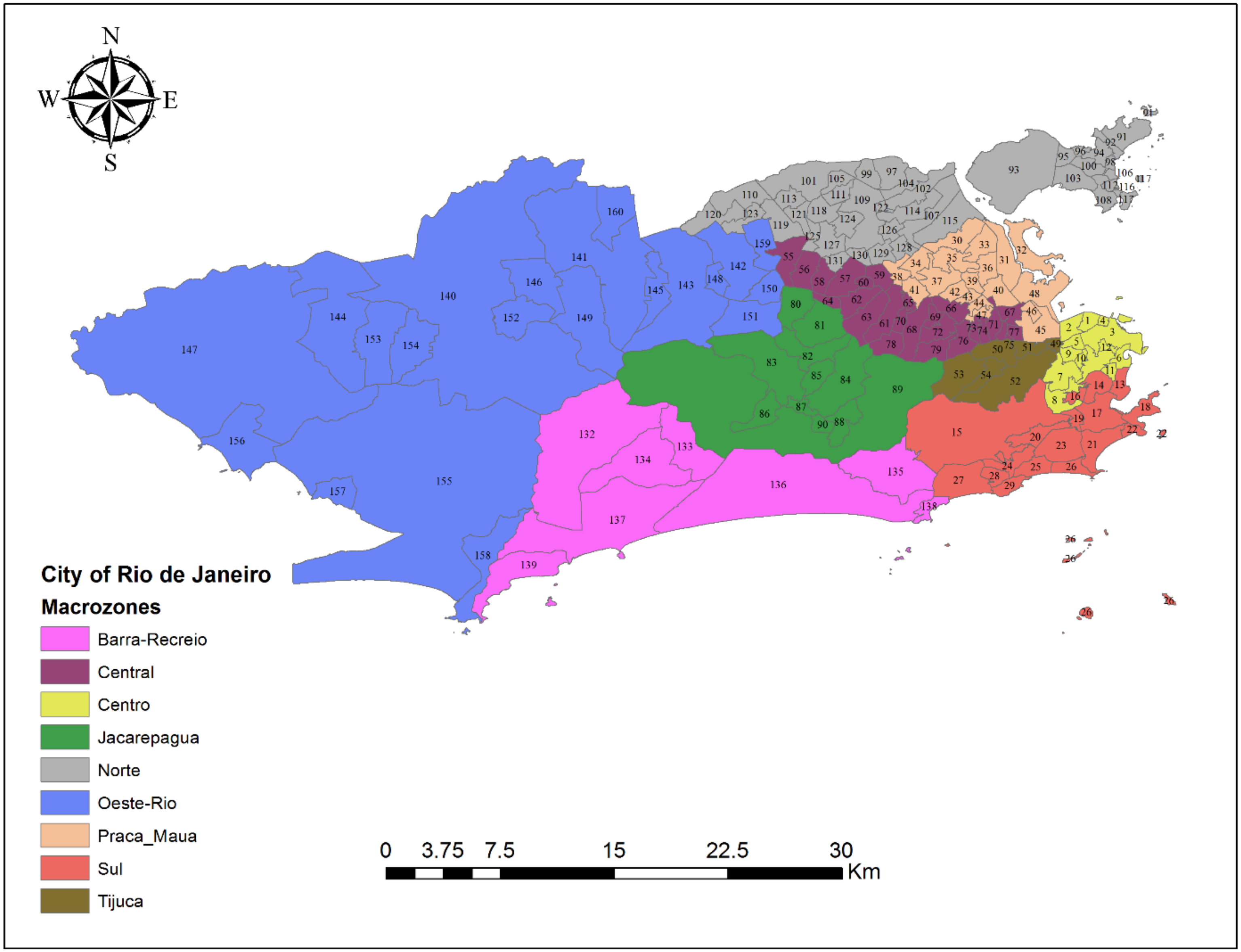


Figure 65: Macrozones of the City of Rio de Janeiro according to the 2010 PDTU Report (Governo do Estado do Rio de Janeiro, 2010)

Table 25: Reference number of the districts based on Figure 65

Ref.	NOME	Macrozone	Ref.	NOME	Macrozone	Ref.	NOME	Macrozone	Ref.	NOME	Macrozone
1	Gamboa	Centro	41	Pilares	Praca_Maua	81	Praça Seca	Jacarepagua	121	Barros Filho	Norte
2	Santo Cristo	Centro	42	Del Castilho	Praca_Maua	82	Tanque	Jacarepagua	122	Vista Alegre	Norte
3	Centro	Centro	43	Maria da Graça	Praca_Maua	83	Taquara	Jacarepagua	123	Ricardo de Albuquerque	Norte
4	Saúde	Centro	44	Jacarezinho	Praca_Maua	84	Freguesia (Jacarepaguá)	Jacarepagua	124	Colégio	Norte
5	Cidade Nova	Centro	45	São Cristóvão	Praca_Maua	85	Pechincha	Jacarepagua	125	Honório Gurgel	Norte
6	Glória	Centro	46	Vasco da Gama	Praca_Maua	86	Curicica	Jacarepagua	126	Vila da Penha	Norte
7	Rio Comprido	Centro	47	Jacaré	Praca_Maua	87	Cidade de Deus	Jacarepagua	127	Rocha Miranda	Norte
8	Santa Teresa	Centro	48	Caju	Praca_Maua	88	Anil	Jacarepagua	128	Vila Kosmos	Norte
9	Estácio	Centro	49	Praça da Bandeira	Tijuca	89	Jacarepaguá	Jacarepagua	129	Vicente de Carvalho	Norte
10	Catumbi	Centro	50	Vila Isabel	Tijuca	90	Gardênia Azul	Jacarepagua	130	Vaz Lobo	Norte
11	Catete	Centro	51	Maracanã	Tijuca	91	Freguesia (Ilha)	Norte	131	Turiaçú	Norte
12	Lapa	Centro	52	Tijuca	Tijuca	92	Bancários	Norte	132	Vargem Grande	Barra-Recreio
13	Flamengo	Sul	53	Grajaú	Tijuca	93	Galeão	Norte	133	Camorim	Barra-Recreio
14	Laranjeiras	Sul	54	Andaraí	Tijuca	94	Tauá	Norte	134	Vargem Pequena	Barra-Recreio
15	Alto da Boa Vista	Sul	55	Marechal Hermes	Central	95	Portuguesa	Norte	135	Itanhangá	Barra-Recreio
16	Cosme Velho	Sul	56	Bento Ribeiro	Central	96	Moneró	Norte	136	Barra da Tijuca	Barra-Recreio
17	Botafogo	Sul	57	Madureira	Central	97	Vigário Geral	Norte	137	Recreio dos Bandeirantes	Barra-Recreio
18	Urca	Sul	58	Osvaldo Cruz	Central	98	Cocotá	Norte	138	Joá	Barra-Recreio
19	Humaitá	Sul	59	Cavalcanti	Central	99	Jardim América	Norte	139	Grumari	Barra-Recreio
20	Jardim Botânico	Sul	60	Engenheiro Leal	Central	100	Jardim Carioca	Norte	140	Campo Grande	Oeste-Rio
21	Copacabana	Sul	61	Piedade	Central	101	Pavuna	Norte	141	Bangu	Oeste-Rio
22	Leme	Sul	62	Cascadura	Central	102	Cordovil	Norte	142	Vila Militar	Oeste-Rio
23	Lagoa	Sul	63	Quintino Bocaiúva	Central	103	Jardim Guanabara	Norte	143	Realengo	Oeste-Rio
24	Gávea	Sul	64	Campinho	Central	104	Parada de Lucas	Norte	144	Paciência	Oeste-Rio
25	Leblon	Sul	65	Abolição	Central	105	Parque Colúmbia	Norte	145	Padre Miguel	Oeste-Rio
26	Ipanema	Sul	66	Cachambi	Central	106	Praia da Bandeira	Norte	146	Santíssimo	Oeste-Rio
27	São Conrado	Sul	67	Benfica	Central	107	Penha Circular	Norte	147	Santa Cruz	Oeste-Rio
28	Rocinha	Sul	68	Engenho de Dentro	Central	108	Cacuia	Norte	148	Magalhães Bastos	Oeste-Rio
29	Vidigal	Sul	69	Todos os Santos	Central	109	Irajá	Norte	149	Senador Camará	Oeste-Rio
30	Olaria	Praca_Maua	70	Encantado	Central	110	Anchieta	Norte	150	Campo dos Afonsos	Oeste-Rio
31	Maré	Praca_Maua	71	Rocha	Central	111	Acari	Norte	151	Jardim Sulacap	Oeste-Rio
32	Cidade Universitária	Praca_Maua	72	Méier	Central	112	Pitangueiras	Norte	152	Senador Vasconcelos	Oeste-Rio
33	Ramos	Praca_Maua	73	Sampaio	Central	113	Costa Barros	Norte	153	Cosmos	Oeste-Rio
34	Engenho da Rainha	Praca_Maua	74	Riachuelo	Central	114	Brás de Pina	Norte	154	Inhoaíba	Oeste-Rio
35	Complexo do Alemão	Praca_Maua	75	São Francisco Xavier	Central	115	Penha	Norte	155	Guaratiba	Oeste-Rio
36	Bonsucesso	Praca_Maua	76	Engenho Novo	Central	116	Zumbi	Norte	156	Sepetiba	Oeste-Rio
37	Inhaúma	Praca_Maua	77	Mangueira	Central	117	Ribeira	Norte	157	Pedra de Guaratiba	Oeste-Rio
38	Tomás Coelho	Praca_Maua	78	Água Santa	Central	118	Coelho Neto	Norte	158	Barra de Guaratiba	Oeste-Rio
39	Higienópolis	Praca_Maua	79	Lins de Vasconcelos	Central	119	Guadalupe	Norte	159	Deodoro	Oeste-Rio
40	Manguinhos	Praca_Maua	80	Vila Valqueire	Jacarepagua	120	Parque Anchieta	Norte	160	Gericinó	Oeste-Rio

Table 26 presents the variables used for the quantitative approach. Figure 66 presents a detailed slope level for cycling. Figure 67 presents the average slope levels for cycling using the data in Figure 67. Figure 68 shows the districts that have access to metro and train inside their area. Figure 69 shows the accessibility to metro and train of all districts, considering a 2.5 km of distance between districts (centroid to centroid of districts), considering the possibility of using the bicycle and disregarding the slope conditions. Figure 70 follows the same pattern from Figure 69, but considers the satisfactory slope conditions, based on the average slope levels.

Table 27 addresses the qualitative variables used to analyse the resilience of urban mobility, in the persistence and adaptability stage. Table 28 presents the qualitative variables used for the transformability analysis of the resilience of urban mobility.

Table 26: Variables for the quantitative approach of the resilience of urban mobility

Type of data	Information (Gov. data bank)
Transportation system and infrastructure	Train; metro; bus (BRT, BRS, Conventional); Car (Private); Cable Car.
Transportation price (until 30 December 2015)	Bus: R$ 3.40 Train: R$ 3.20 Metro: R$ 3.70 Bus-Bus: R$ 3.40 Bus-Metro: R$ 4.95 Bus-Train: R$ 4.70 Metro-Train: R$ 5.90 Car: – Gasoline R$ 3.20/litre – Alcohol R$ 2.30/litre – Other fuel types were not considered Cable Car: R$ 1.00 Motorcycle: Not considered Ferry: Not considered Informal: Not considered
Wage	Seven wage parameters from each district
Matrix of expenditure	Based on the data bank of IBGE – National Scale
Job positions	Based on the data bank the city of Rio de Janeiro
Origin and Destination	Centroid to centroid distance (km) between all district as a matrix
Slope data	Average slope values for each district of the city

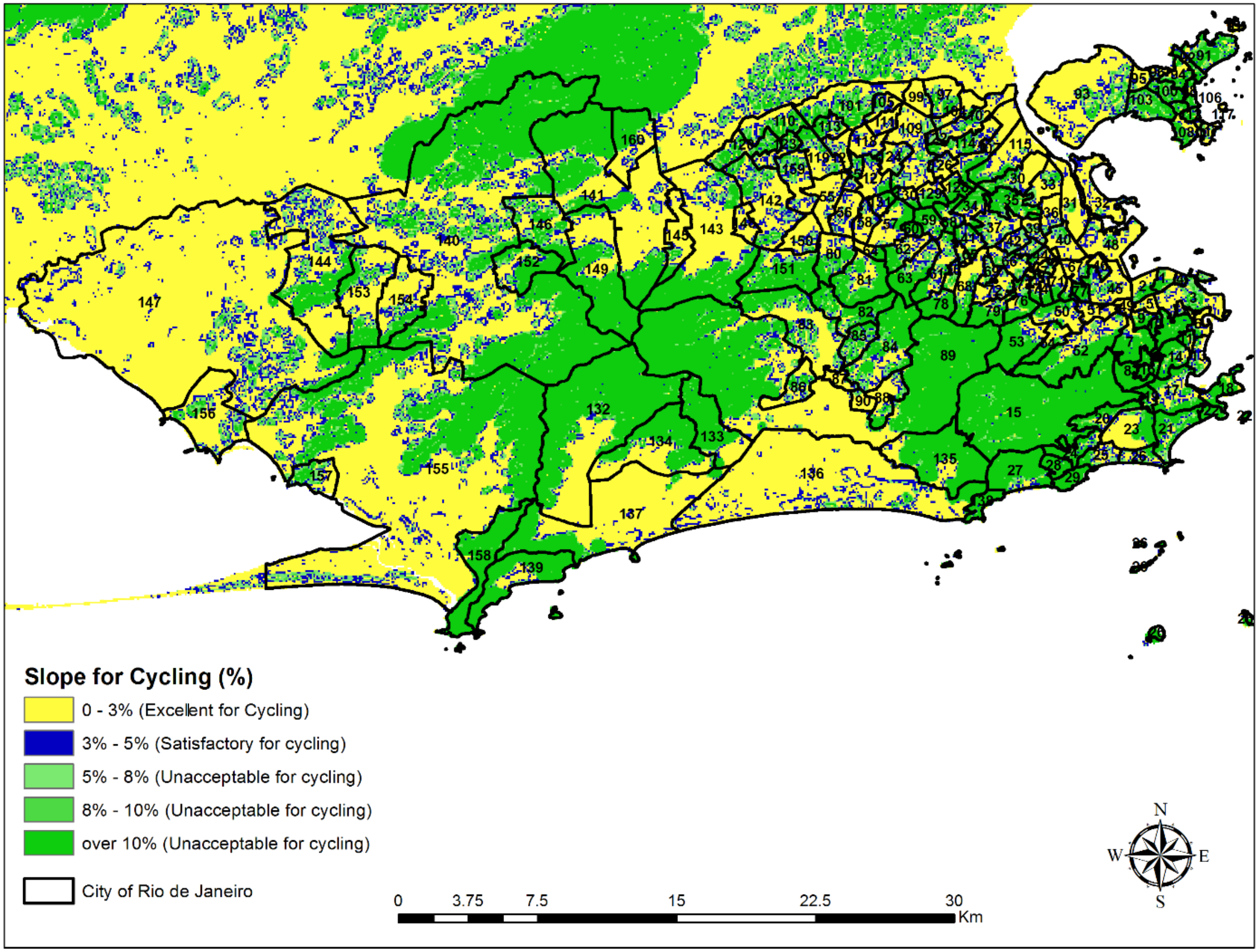


Figure 66: Slope Levels for Cycling in the City of Rio de Janeiro – Slope Values Based on Bicycle Network (2015)

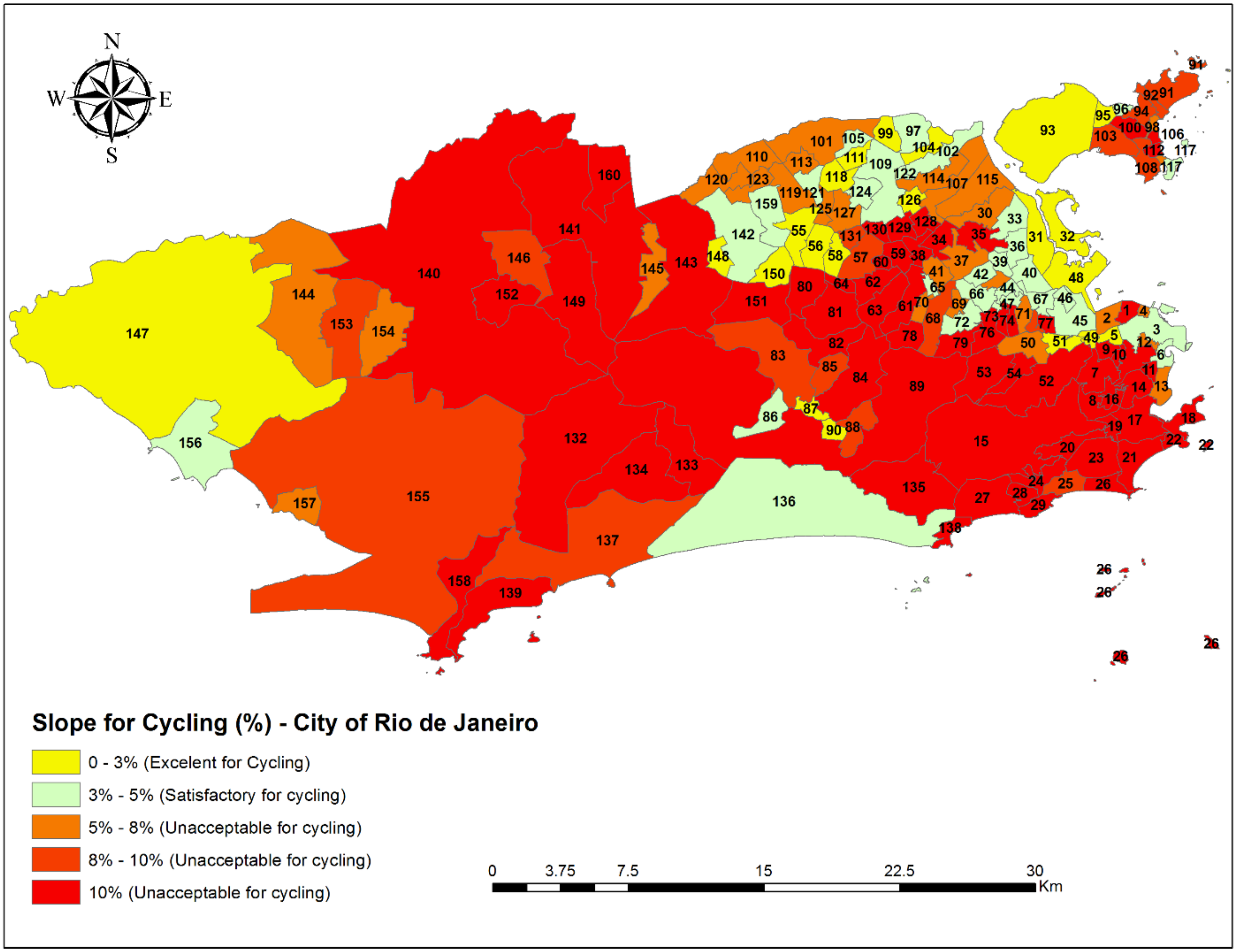


Figure 67: Average Slope Values for each District of the City of Rio de Janeiro

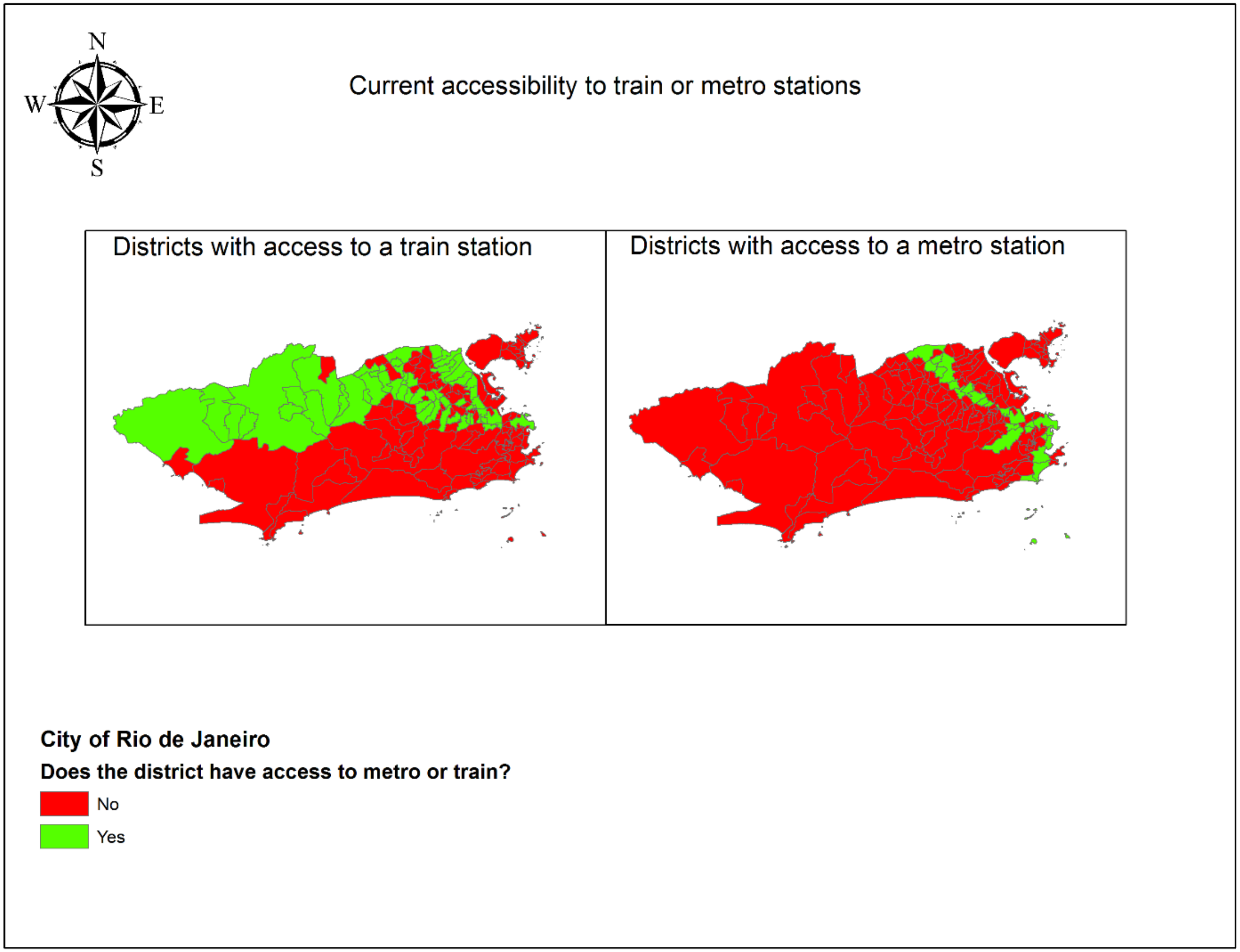


Figure 68: Districts with Metro and Train Stations

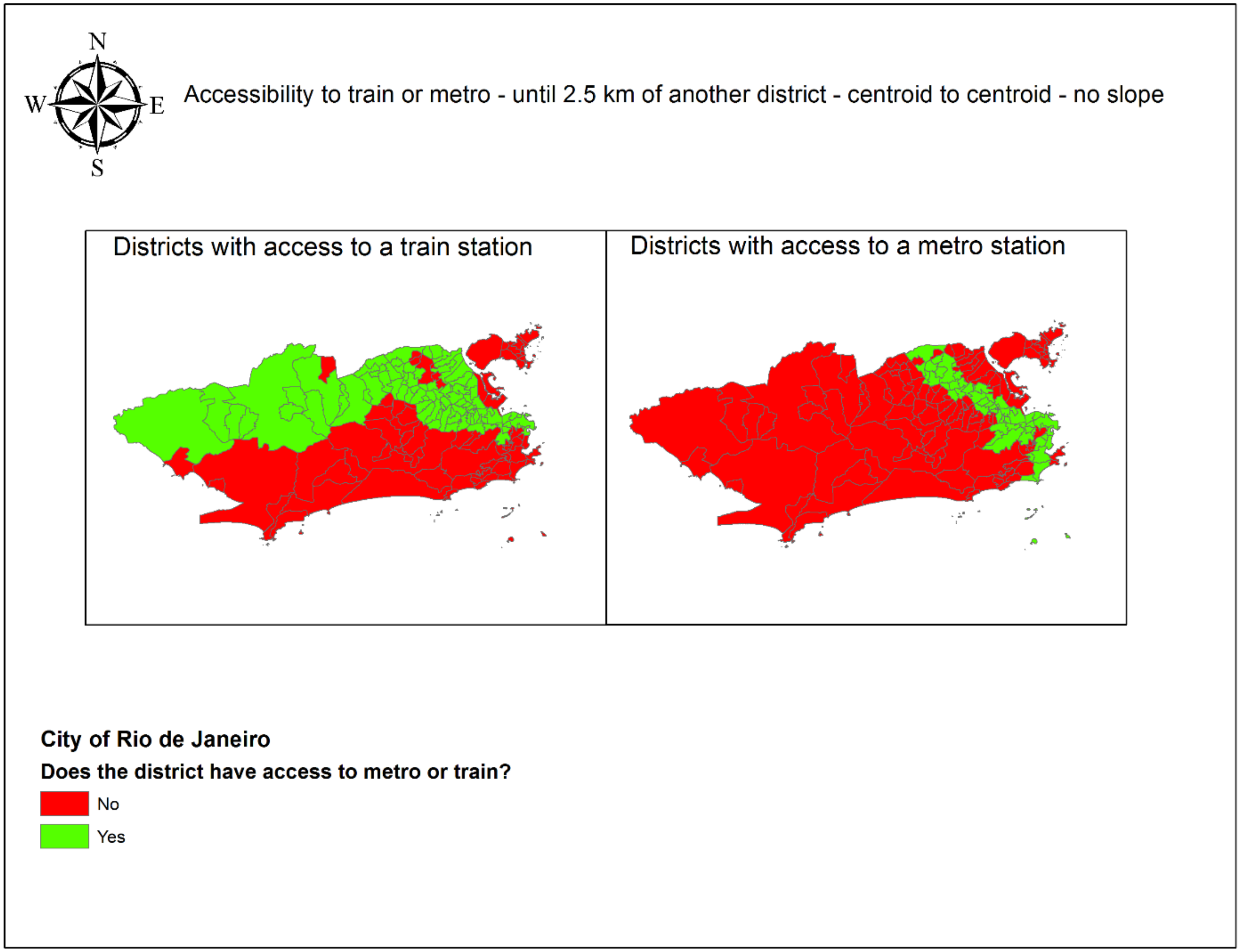


Figure 69: District with access to Metro and Train station within a 2.5 km distance – Centroid to Centroid – Disregarding Slope Conditions

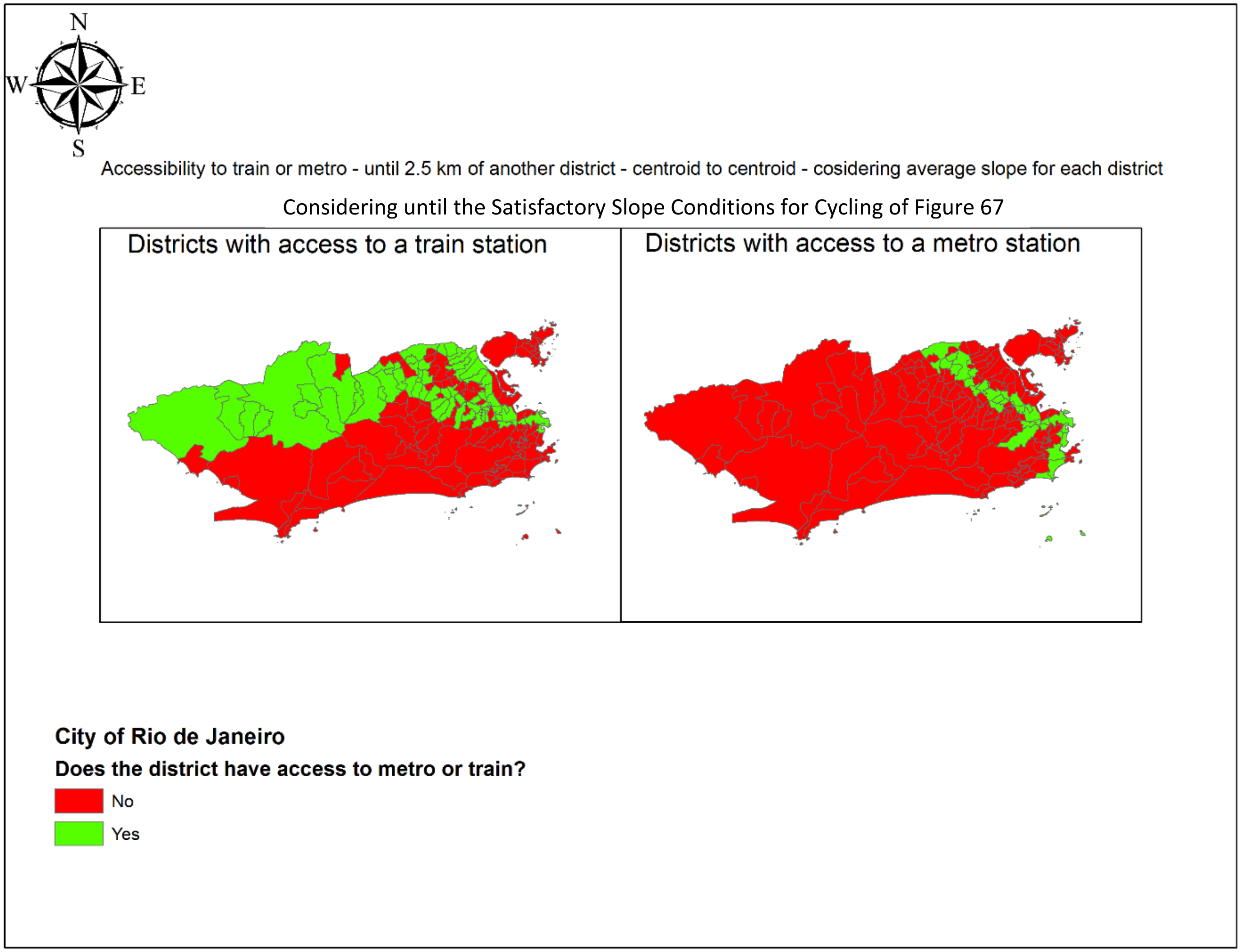


Figure 70: District with access to Metro and Train station within a 2.5 km distance – Centroid to Centroid – Considering Slope Conditions

Table 27: Variables for the qualitative approach on the resilience of urban mobility

Elements	Questions and Data Gathered	
	Users of Private and Public Transportation	Researchers and professionals
Socioeconomic	- Age; - Gender; - Wage; - Education level; - Do transportation costs affect personal or family costs?	- Do citizens benefit from current mobility conditions from the social and economic perspective? - Do you think that transportation costs affect personal cost of the users?
Attitude data	- Why private, public or both? - Possible reaction face to scenarios H2, H3 and H4; - Possibility of cycling to an metro or train station;	- Do you think that Rio de Janeiro is dependent on fossil fuels? - Does the public transportation system has capacity to absorb 50% or 100% of private transportation users? - How would the urban mobility be affected in scenarios H2 or H3?
Origin and destination	- Origin and destination of the questionnaire respondents.	
Attractiveness	- How easy or difficult it is, to find a job and services in the same or neighbouring district?	
Matrix of expenditure	- Does contractor pay for transportation costs? - How much is spent with transportation, monthly; - Matrix of expenditure; - Order of importance of expenses.	
Mobility patterns	- Modal choice; - Most used fuel, if private transportation; - Travel time for origin to destination.	- Do you think that the sense of security affects the modal choice?

Table 28: Variable of transformability for the resilience of urban mobility analysis

<table>
<tr><th rowspan="2">Type of data</th><th colspan="2">Questions and Data Gathered</th></tr>
<tr><th>Users of Private and Public Transportation</th><th>Researchers and professionals</th></tr>
<tr><td>Social Movements</td><td>- Do you believe that social movements are important to improve urban mobility?
- Did you ever took part in a social movement?</td><td>- Do you believe that social movements are important to improve urban mobility?</td></tr>
<tr><td>Public and private sector</td><td>- Is there a belief that the private or/and public sector would mitigate the threat?</td><td>- Is there, currently, transport or mobility policies, which are concerned with reducing the use of fossil fuels?</td></tr>
<tr><td>Public Transportation</td><td></td><td>- What is the difficulty of increasing the use of renewable energy in the transport sector?
- Are you aware of any solution, currently, in the transportation sector, which are based on this concept?
- Is there a way for the urban mobility reach a 100% use of renewable energy today, at a short or medium term period?</td></tr>
<tr><td>Attitude</td><td>- Order of concerns regarding transportation aspect: pollution, time, comfort and price.</td><td rowspan="3">- What is the function and importance of transport planning in cities?
- Is transport planning in cities practiced through an interdisciplinary and multidisciplinary perspective?
- What are the problems regarding urban mobility in the city?
- Do sustainable solutions bring social and economic benefits, which?
- Do you think that social inequity is related to urban mobility? How?</td></tr>
<tr><td>Built environment</td><td></td></tr>
<tr><td>Attractiveness</td><td></td></tr>
<tr><td>Right to Urban Mobility</td><td></td><td>- What is your opinion on participative transport planning?
- Does it exist? If it exists, would you define this participation as high, medium or low?</td></tr>
</table>

8.3. Persistence and Adaptability Evaluation

When analysing the results, it is interesting to show part of them concerning whether the respondents like or not to use private or public transportation. These responses show one of the reasons why it is suitable to divide the sample on the three proposed groups (private, public and both transportation users).

Table 29: Responses of the sample concerning whether they like or not to use private or public transportation

Affirmations	Private	Public	Both
"I like to go by public transportation"	0%	8%	7%
"I like to go by private transportation"	49%	0%	38%

According to Table 29, it is possible to observe that 49% like to use private transportation, while 8% said that they like to use public transportation. Furthermore, from those who use both types of transportation, 7% like to use public transportation and 38% like to use private transportation. For public transportation users' case, it is more of a necessary choice, meaning that there is no other option. For those who use private transportation, there may be a tendency to value more comfort and privacy conditions, than the price. For those who use both types, they present more ideological flexibility towards choosing private or public transportation and may have a mixture of values, regarding comfort and privacy, but also valuing price and transportation expenditure.

The following sections, 8.3.1 and 8.3.2, present the results of the case study from a quantitative and qualitative approach for analysing the persistence and adaptability of the resilience of urban mobility.

8.3.1. Quantitative Results

This section analyses the results based on the Brazilian government's official data (IBGE[9] and Governo do Estado do Rio de Janeiro[10]). The data collected from IBGE (*Instituto Brasileiro de Geografia e Estatística* – Brazilian Institute for Geography and Statistic) has higher statistical validity and offers data from national to district scale. Table 30 presents the matrix of expenditure at a national scale, by ranges of salary. The "a", "b","c" and "d" refers to expenses presented in

[9] http://www.ibge.gov.br/home/
[10] http://www.rj.gov.br/

Table 13. Furthermore, Table 31 presents the wage parameter used in this section, in order to present the number of people within each income.

Table 30: Wage used for the resilience of urban mobility evaluation and matrix of expenditure (IBGE, 2010)

Salary Used in the Model	a	b	c	d
R$ 394.00	80.0%	8.3%	2.9%	8.8%
R$ 788.00	80.0%	8.3%	2.9%	8.8%
R$ 1,576.00	70.1%	11.9%	4.7%	13.3%
R$ 3,940.00	62.5%	14.2%	7.1%	16.2%
R$ 7,880.00	52.7%	19.9%	7.9%	19.5%
R$ 15,760.00	44.2%	25.5%	12.8%	17.5%
Over R$ 15,760.00	44.2%	25.5%	12.8%	17.5%

Table 31: Wage ranges used in the model and codes

Wage ranges (parameters)	Code
until R$ 394.00	W1
From R$ 394.00 to R$ 788.00	W2
From 788.00 to R$ 1,576.00	W3
From R$ 1,576.00 to R$ 3,940.00	W4
From R$ 3,940.00 to R$ 7,880.00	W5
From R$ 7,880.00 to R$ 15,760.00	W6
Over R$ 15,760.00	W7

Table 32 presents the group of data that are analysed in this section. There is a group of data based on the government data bank. It is a group of 1,920 samples (considering optimistic and pessimistic scenarios), because there are 160 districts in the city of Rio de Janeiro, and for each district 12-wage levels were tested.

Table 32: Group of data analysed – description – sample size

Group of analysis	Description	Sample size
IBGE data	Based on the Brazilian government data bank	1,920

Table 33 addresses the proposed four threat scenarios to evaluate the resilience of urban mobility of Rio de Janeiro, through the quantitative approach. There are the H2, H3 and H4 threat scenarios, which are described in the same table. In addition to these scenarios, the H1 scenario represents the model applying the current price condition, which is used for the persistence stage of analysis. It is possible to observe that although this research proposes the evaluation of the resilience of urban mobility in light of the fossil fuel dependency, it also suggests the increase in the alcohol price. The reason for this increase is that during the fieldwork in Rio de Janeiro, from 6th October until 5th December, the price of gasoline increased, along with the increase in alcohol price in the same proportion, which at the time was approximately 20%.

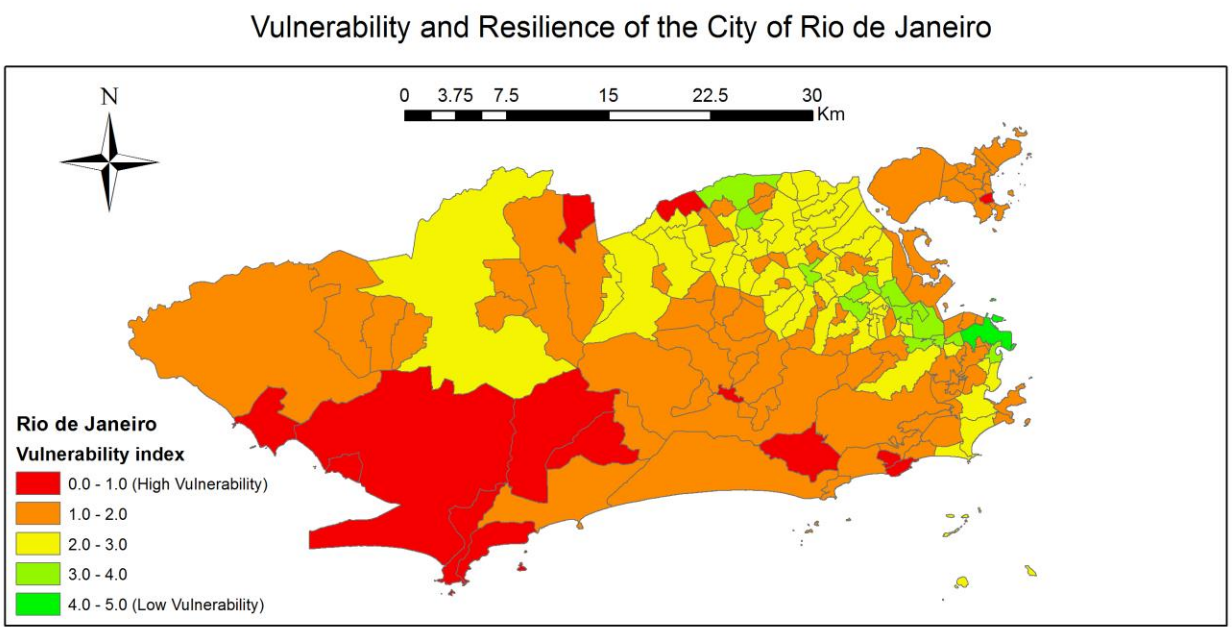
Table 33: Hypothetical threats used in for the study case analysis

Hypothetical threats	Description
H2	Increase of 50% of oil-based public transportation fares and gasoline/alcohol price per litre
H3	Increase of 100% of oil-based public transportation fares and gasoline/alcohol price per litre
H4	No oil-based public transportation and fuel available; Maintaining alcohol same as in the H3 scenario.

Due to the uncertainty of what could happen to alcohol price if gasoline was not available, for the H4 scenario, the price of the H3 scenario is maintained.

The following sub-section represents the results through maps (8.3.1.1), following the proposed methodology in this thesis. Moreover, section 8.3.1.2 analyses the maps of section 8.3.1.1.

8.3.1.1. *Representation of the Results through Maps*



Multiple linear regression model				
Variable	H1	H2	H3	H4
Dependent Variable	RUMIif (H1 -O and P)	RUMIif (H2 -O and P)	RUMIif (H3 -O and P)	RUMIif (H4 -O and P)
Independent Variables	WageN; MetroN; TrainN; JobN; DistanceN			

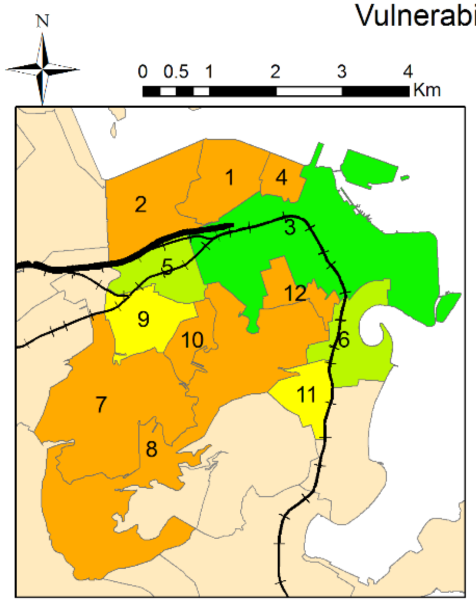
City	Rio de Janeiro		
RUMI	High	Medium	Low
H1 (O)	97.50%	2.50%	0.00%
H2 (O)	88.75%	11.25%	0.00%
H3 (O)	63.75%	35.63%	0.63%
H4 (O)	42.50%	47.50%	10.00%
H1 (P)	29.38%	65.00%	5.63%
H2 (P)	18.75%	60.00%	21.25%
H3 (P)	15.00%	53.13%	31.88%
H4 (P)	11.25%	40.00%	48.75%

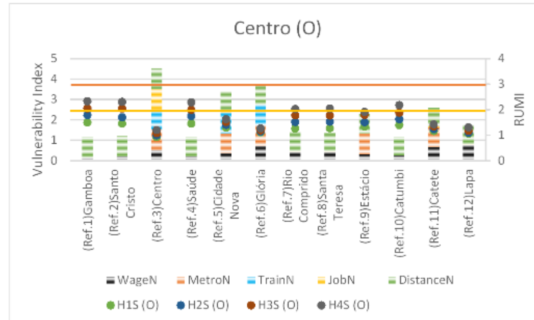
Multiple linear regression model			
Cases	Adjusted R Square	F	P from F
H1 (O)	0.879	231.019	0.00
H2 (O)	0.915	343.488	0.00
H3 (O)	0.937	473.663	0.00
H4 (O)	0.905	302.323	0.00
H1 (P)	0.936	467.553	0.00
H2 (P)	0.965	868.215	0.00
H3 (P)	0.954	655.817	0.00
H4 (P)	0.887	250.259	0.00

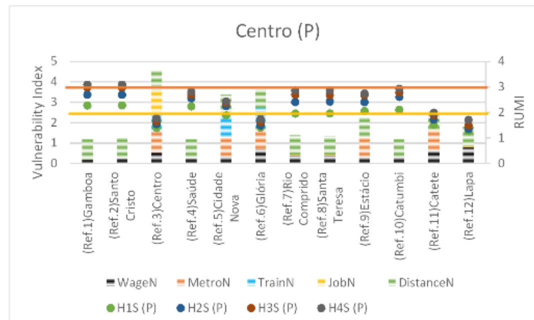
Multiple linear regression model									
Independent Variables	Output	H1 (O)	H2 (O)	H3 (O)	H4 (O)	H1 (P)	H2 (P)	H3 (P)	H4 (P)
WageN	p from t	0	0	0	0	0	0	0	0
	B	0.26	0.364	0.444	0.524	0.573	0.674	0.66	0.605
MetroN	p from t	0.569	0.045	0	0	0.041	0	0	0
	B	0.003	0.01	0.028	0.049	0.014	0.023	0.038	0.059
TrainN	p from t	0.689	0	0	0	0.331	0	0	0
	B	-0.002	0.024	0.062	0.131	-0.006	0.029	0.054	0.096
JobN	p from t	0	0	0.001	0.247	0	0	0	0.007
	B	0.104	0.093	0.084	0.05	0.154	0.138	0.143	0.131
DistanceN	p from t	0	0	0	0	0	0	0	0
	B	0.07	0.068	0.076	0.239	0.105	0.083	0.069	0.151

Figure 71: Vulnerability Index and multiple linear regression results

Vulnerability and RUMI of the Macrozone "Centro"







Centro

Vulnerability Index*

- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0 (Low Vulnerability)

Rail Transport Systems

Metro and Train

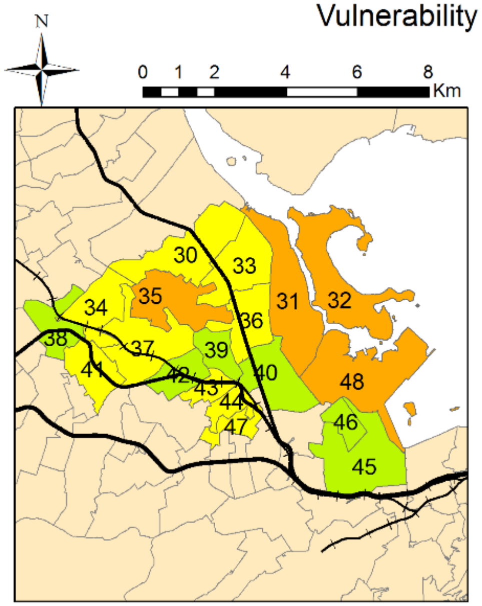
- METRO
- URBAN TRAIN

Macrozone	Centro		
RUMI	High	Medium	Low
H1 (O)	100.00%	0.00%	0.00%
H2 (O)	100.00%	0.00%	0.00%
H3 (O)	83.33%	16.67%	0.00%
H4 (O)	50.00%	50.00%	0.00%
H1 (P)	58.33%	41.67%	0.00%
H2 (P)	33.33%	66.67%	0.00%
H3 (P)	33.33%	66.67%	0.00%
H4 (P)	33.33%	50.00%	16.67%

* No district has a high vulnerability level

Figure 72: Vulnerability and Index of Urban Resilience of the Macrozone "Centro"

Vulnerability and RUMI of the Macrozone "Praca_Maua"



Praca_Maua

Vulnerability Index*

1.0 - 2.0

2.0 - 3.0

3.0 - 4.0

4.0 - 5.0 (Low Vulnerability)

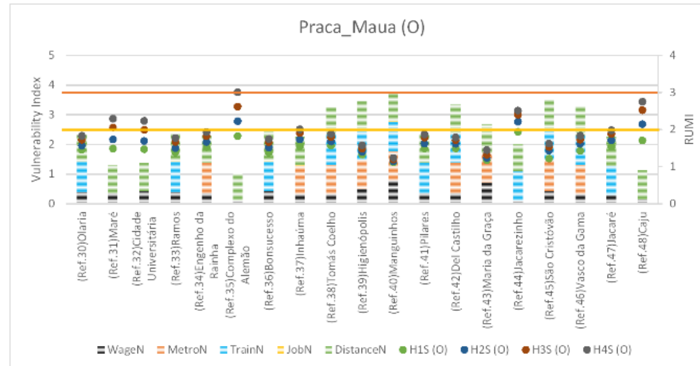
Rail Transport Systems

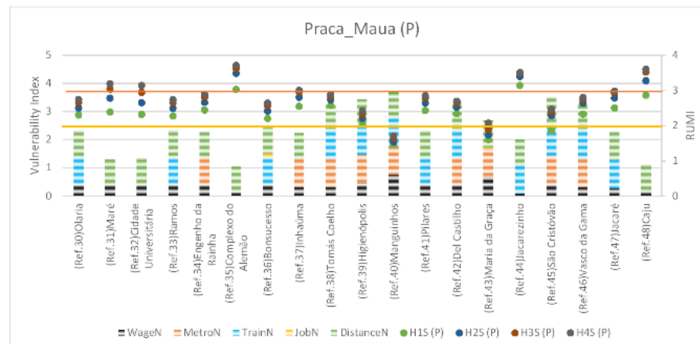
Metro and Train

METRO

URBAN TRAIN

* No district has a high vulnerability level

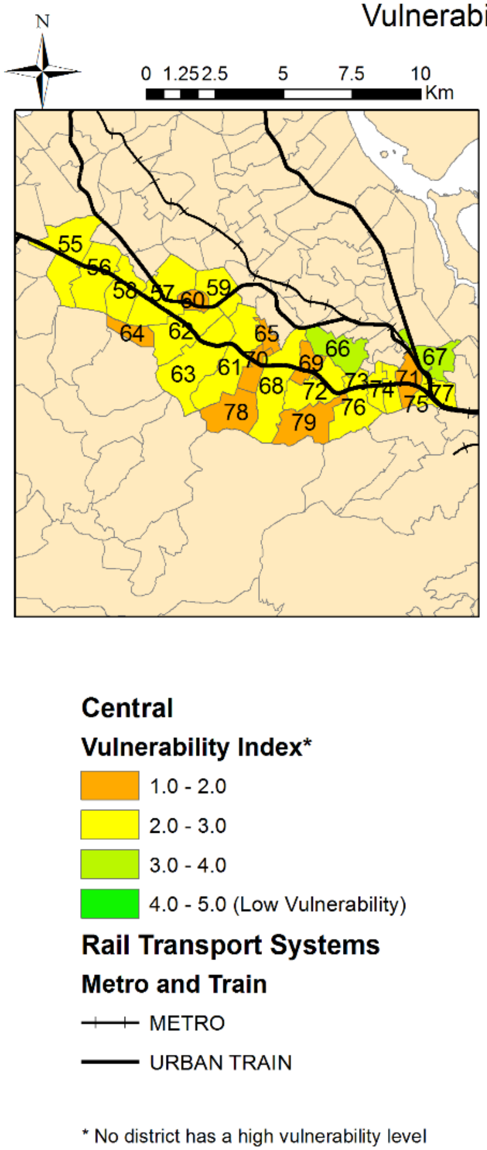


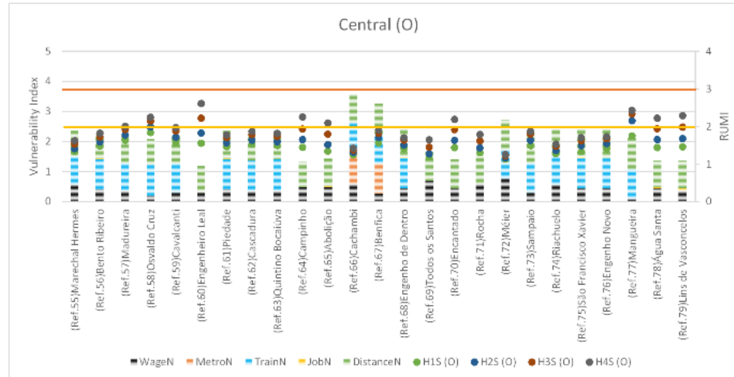


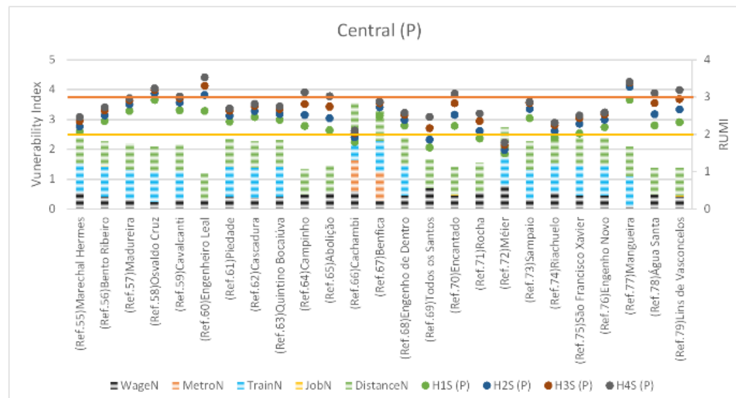
Macrozone	Praca_Maua		
RUMI	High	Medium	Low
H1 (O)	100.00%	0.00%	0.00%
H2 (O)	84.21%	15.79%	0.00%
H3 (O)	78.95%	21.05%	0.00%
H4 (O)	68.42%	26.32%	5.26%
H1 (P)	15.79%	73.68%	10.53%
H2 (P)	10.53%	73.68%	15.79%
H3 (P)	10.53%	68.42%	21.05%
H4 (P)	5.26%	63.16%	31.58%

Figure 73: Vulnerability and Index of Urban Resilience of the Macrozone “Praca_Maua”

Vulnerability and RUMI of the Macrozone "Central"



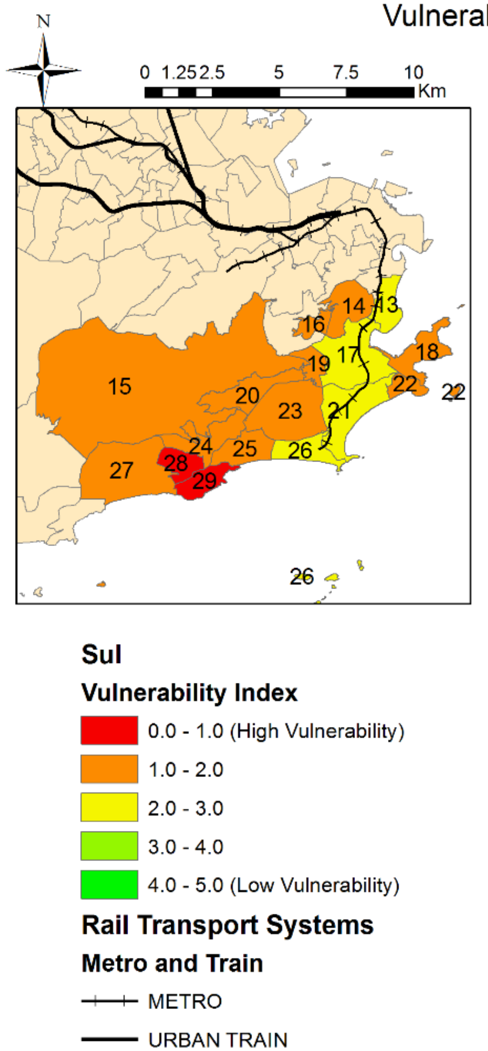


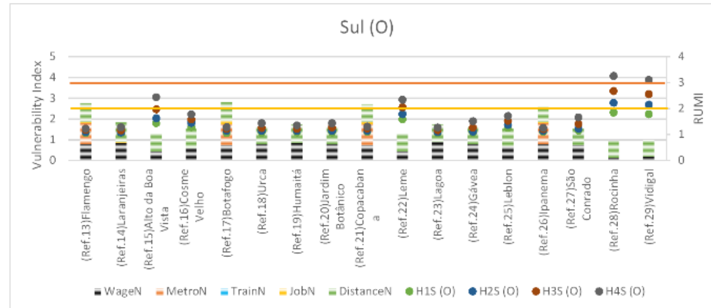


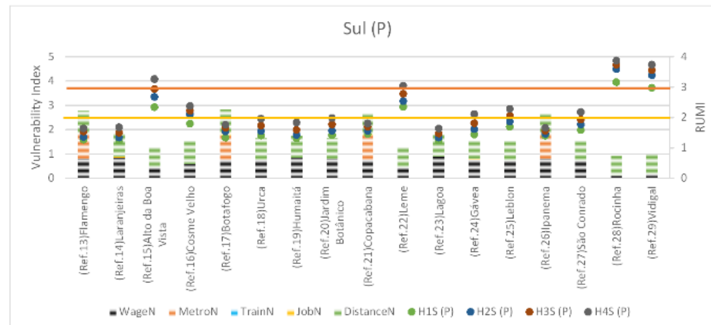
Macrozone	Central		
RUMI	High	Medium	Low
H1 (O)	100.00%	0.00%	0.00%
H2 (O)	96.00%	4.00%	0.00%
H3 (O)	88.00%	12.00%	0.00%
H4 (O)	64.00%	36.00%	0.00%
H1 (P)	20.00%	80.00%	0.00%
H2 (P)	12.00%	76.00%	12.00%
H3 (P)	4.00%	84.00%	12.00%
H4 (P)	4.00%	60.00%	36.00%

Figure 74: Vulnerability and Index of Urban Resilience of the Macrozone "Central"

Vulnerability and RUMI of the Macrozone "Sul"



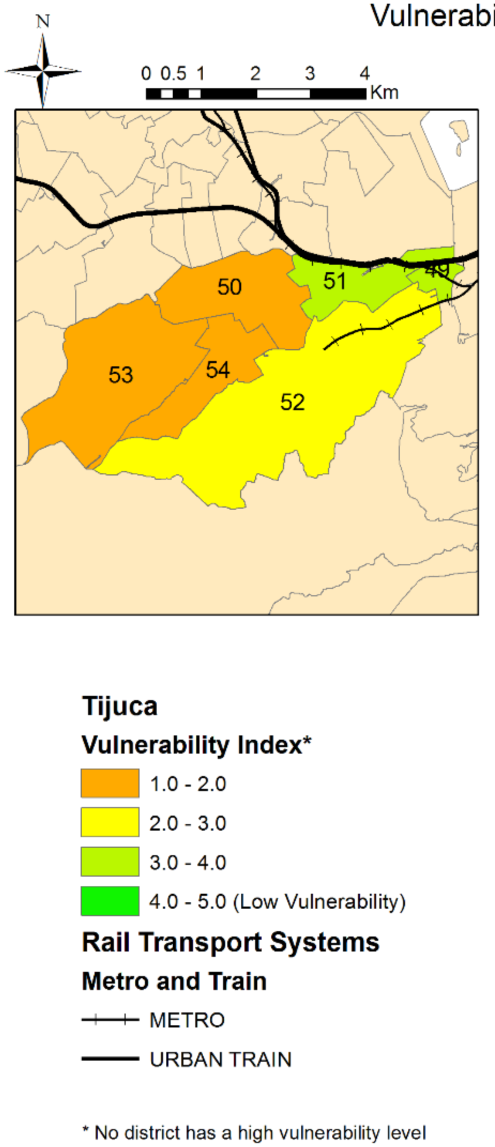


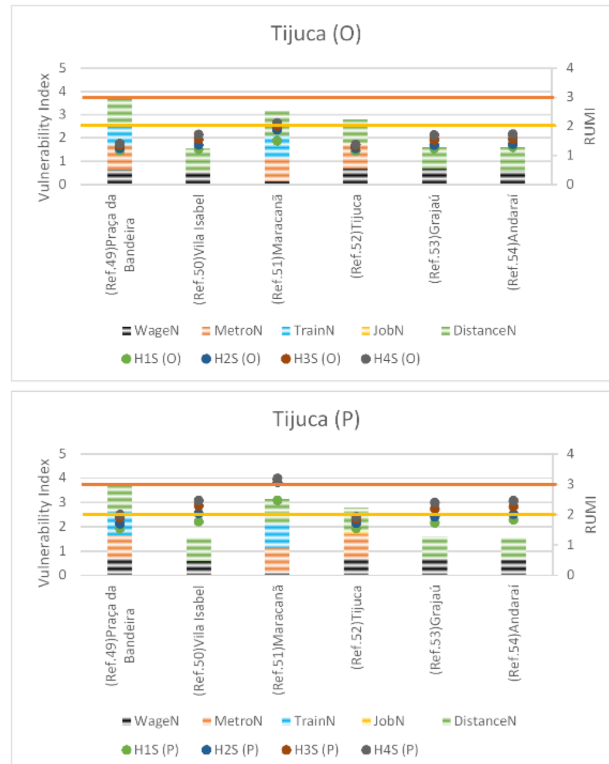


Macrozone	Sul		
RUMI	High	Medium	Low
H1 (O)	100.00%	0.00%	0.00%
H2 (O)	88.24%	11.76%	0.00%
H3 (O)	82.35%	17.65%	0.00%
H4 (O)	76.47%	11.76%	11.76%
H1 (P)	76.47%	17.65%	5.88%
H2 (P)	70.59%	17.65%	11.76%
H3 (P)	64.71%	23.53%	11.76%
H4 (P)	52.94%	23.53%	23.53%

Figure 75: Vulnerability and Index of Urban Resilience of the Macrozone “Sul”

Vulnerability and RUMI of the Macrozone "Tijuca"

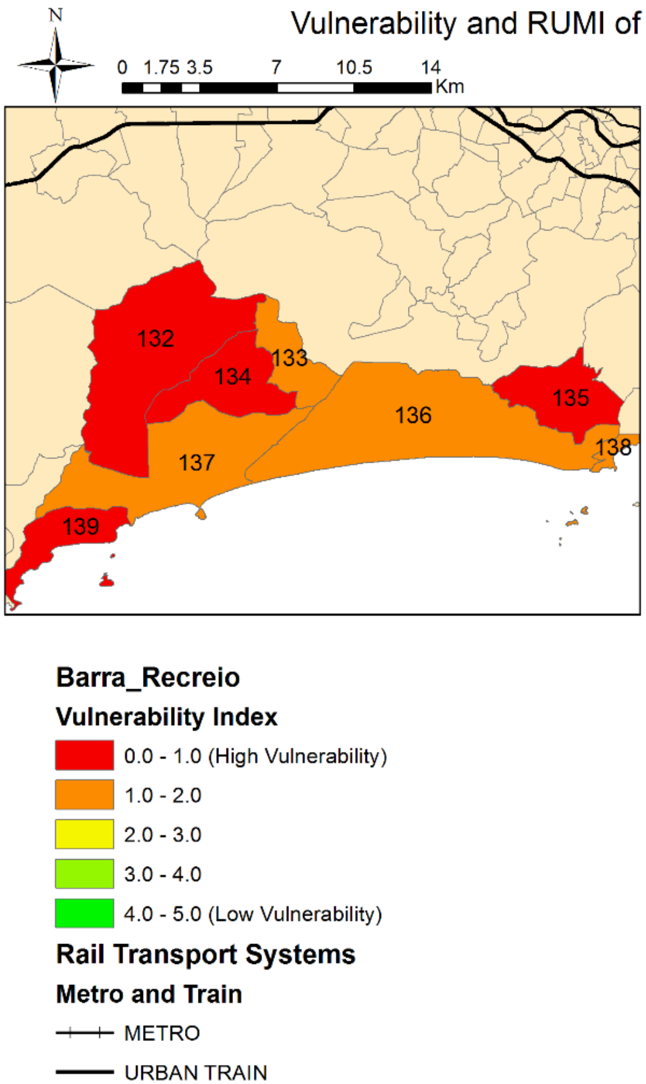


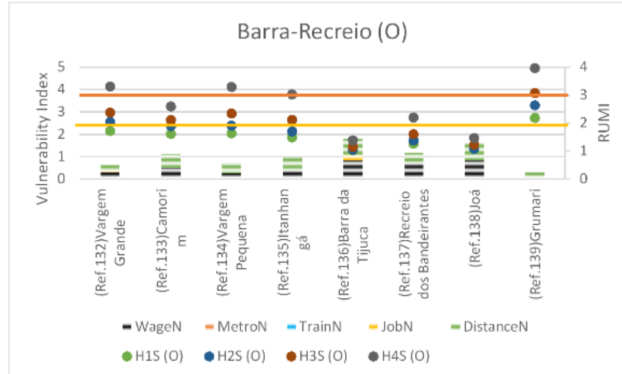


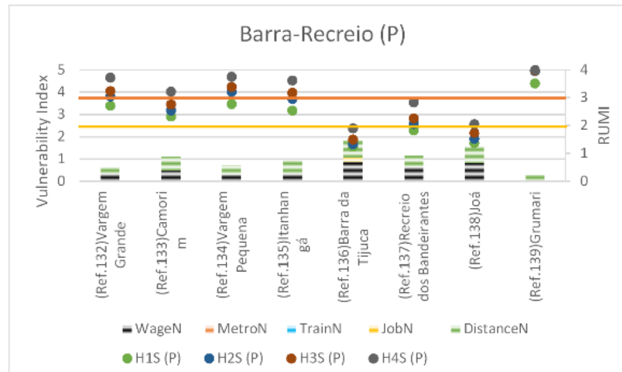
Macrozone	Tijuca		
RUMI	High	Medium	Low
H1 (O)	100.00%	0.00%	0.00%
H2 (O)	100.00%	0.00%	0.00%
H3 (O)	83.33%	16.67%	0.00%
H4 (O)	83.33%	16.67%	0.00%
H1 (P)	83.33%	16.67%	0.00%
H2 (P)	50.00%	33.33%	16.67%
H3 (P)	33.33%	50.00%	16.67%
H4 (P)	33.33%	50.00%	16.67%

Figure 76: Vulnerability and Index of Urban Resilience of the Macrozone "Tijuca"

Vulnerability and RUMI of the Macrozone "Barra-Recreio"



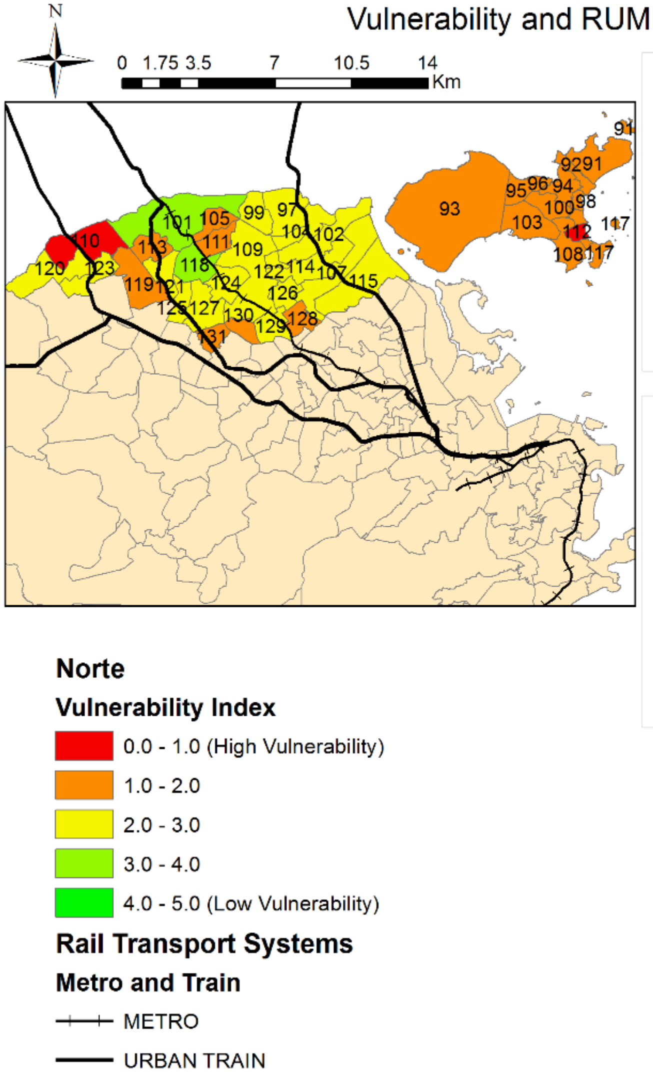


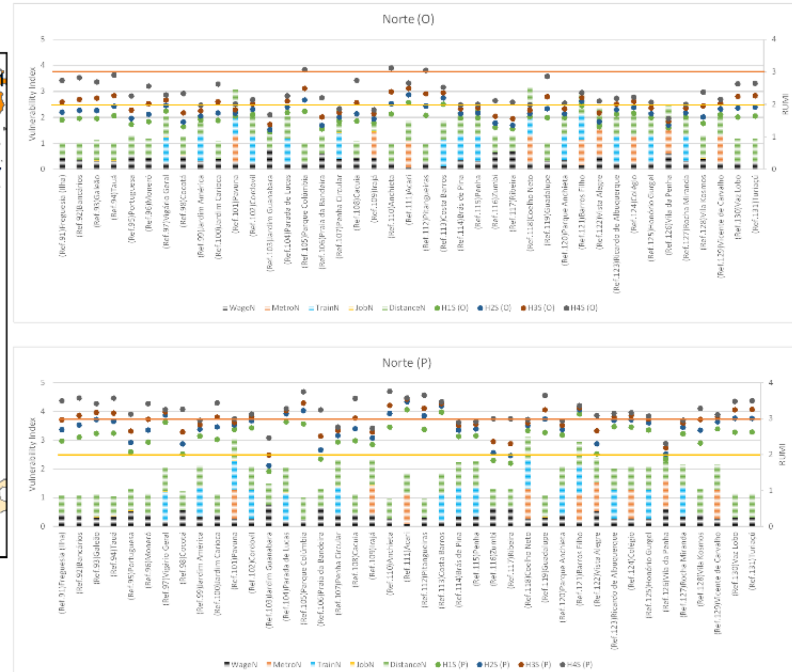


Macrozone	Barra-Recreio		
RUMI	High	Medium	Low
H1 (O)	87.50%	12.50%	0.00%
H2 (O)	75.00%	25.00%	0.00%
H3 (O)	37.50%	50.00%	12.50%
H4 (O)	25.00%	25.00%	50.00%
H1 (P)	37.50%	50.00%	12.50%
H2 (P)	25.00%	37.50%	37.50%
H3 (P)	25.00%	25.00%	50.00%
H4 (P)	12.50%	25.00%	62.50%

Figure 77: Vulnerability and Index of Urban Resilience of the Macrozone "Barra-Recreio"

Vulnerability and RUMI of the Macrozone "Norte"

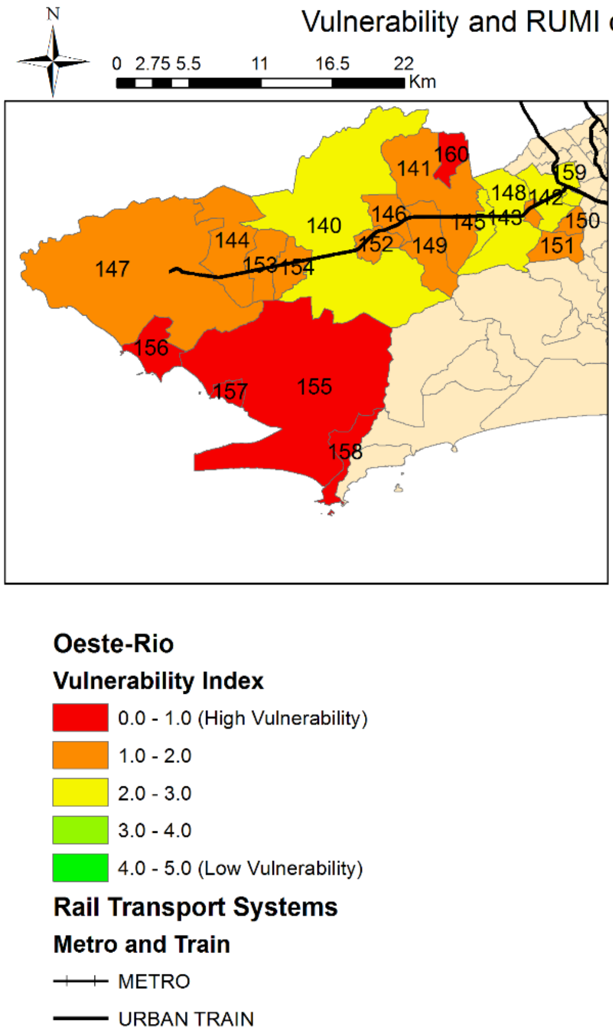


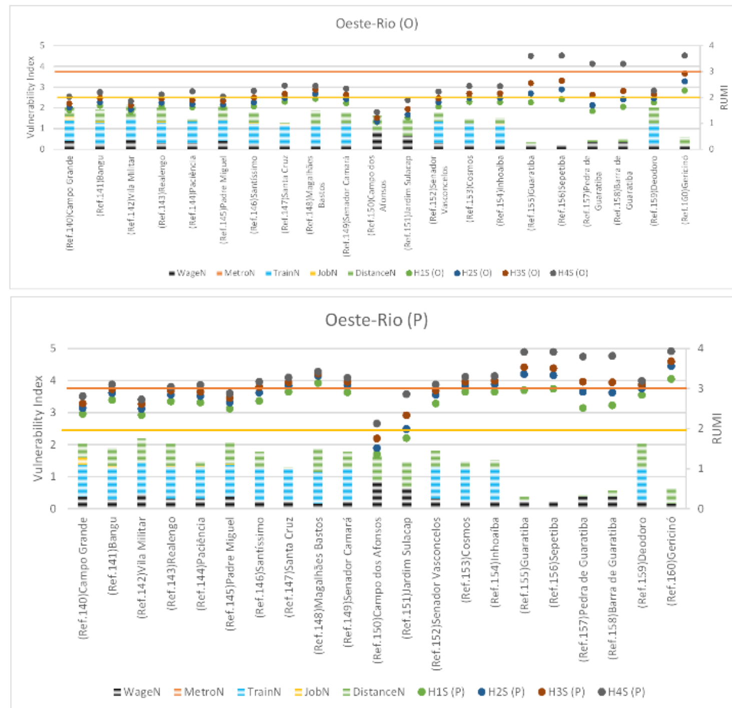


Macrozone	Norte		
RUMI	High	Medium	Low
H1 (O)	95.12%	4.88%	0.00%
H2 (O)	87.80%	12.20%	0.00%
H3 (O)	46.34%	53.66%	0.00%
H4 (O)	19.51%	73.17%	7.32%
H1 (P)	12.20%	80.49%	7.32%
H2 (P)	4.88%	70.73%	24.39%
H3 (P)	2.44%	48.78%	48.78%
H4 (P)	0.00%	31.71%	68.29%

Figure 78: Vulnerability and Index of Urban Resilience of the Macrozone “Norte”

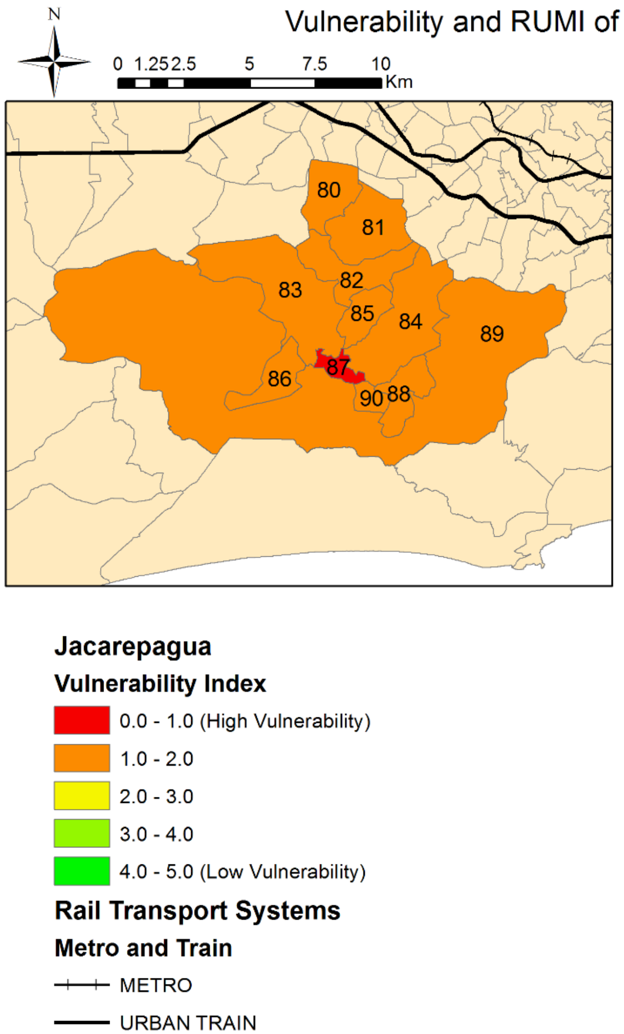
Vulnerability and RUMI of the Macrozone "Oeste-Rio"

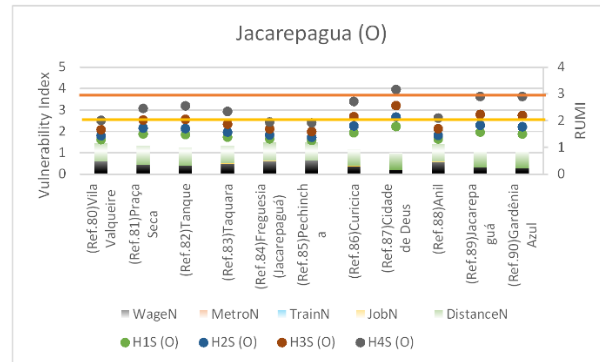


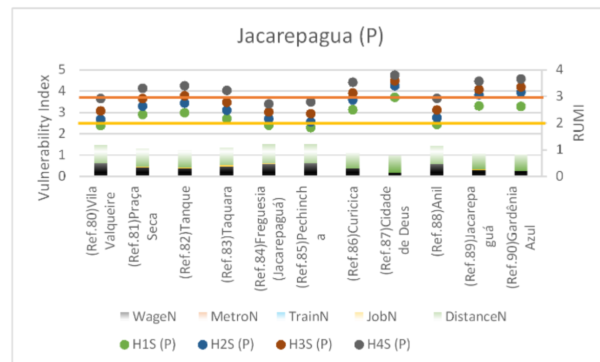


Macrozone	Oeste-Rio		
RUMI	High	Medium	Low
H1 (O)	95.24%	4.76%	0.00%
H2 (O)	80.95%	19.05%	0.00%
H3 (O)	42.86%	57.14%	0.00%
H4 (O)	14.29%	61.90%	23.81%
H1 (P)	9.52%	80.95%	9.52%
H2 (P)	9.52%	47.62%	42.86%
H3 (P)	4.76%	38.10%	57.14%
H4 (P)	0.00%	23.81%	76.19%

Figure 79: Vulnerability and Index of Urban Resilience of the Macrozone "Oeste-Rio"







Macrozone	Jacarepagua		
RUMI	High	Medium	Low
H1 (O)	100.00%	0.00%	0.00%
H2 (O)	90.91%	9.09%	0.00%
H3 (O)	45.45%	54.55%	0.00%
H4 (O)	18.18%	72.73%	9.09%
H1 (P)	36.36%	63.64%	0.00%
H2 (P)	0.00%	72.73%	27.27%
H3 (P)	0.00%	54.55%	45.45%
H4 (P)	0.00%	36.36%	63.64%

Figure 80: Vulnerability and Index of Urban Resilience of the Macrozone "Jacarepagua"

8.3.1.2. *Analysis of the Quantitative Results*

Before starting the analysis, we can clarify that the weighted average of the resilience index based on the number of job positions of each district causes an effect on the index, giving more importance to the accessibility level of the 160 district of Rio de Janeiro to the districts with more job positions. Table 34 show all districts from the 160 that have equal or more than 1% of the job positions in relation to the whole city. Through this filter, 18 districts were identified. Furthermore, the 18 districts compose of 66.6% of all the job positions in the city, where one (Centro) has 27.7% of the 66.6%.

Table 34: Presence of metro and train station in the districts with equal or more than 1% of job positions in relation to the whole city of Rio de Janeiro

Ref.	**District**	**Macrozone**	**Metro**	**Train**	**Job (%)**
3	Centro	Centro	Yes	Yes	27.7%
7	Rio Comprido	Centro	No	No	1.4%
14	Laranjeiras	Sul	Yes	No	1.0%
17	Botafogo	Sul	Yes	No	3.7%
21	Copacabana	Sul	Yes	No	2.2%
26	Ipanema	Sul	Yes	No	1.2%
33	Ramos	Praca_Maua	No	Yes	1.1%
36	Bonsucesso	Praca_Maua	No	Yes	2.5%
40	Manguinhos	Praca_Maua	No	Yes	1.0%
45	São Cristóvão	Praca_Maua	Yes	Yes	3.1%
52	Tijuca	Tijuca	Yes	No	3.3%
79	Lins de Vasconcelos	Central	No	No	1.0%
83	Taquara	Jacarepagua	No	No	1.3%
115	Penha	Norte	No	Yes	1.1%
136	Barra da Tijuca	Barra-Recreio	No	No	6.3%
140	Campo Grande	Oeste-Rio	No	Yes	6.1%
141	Bangu	Oeste-Rio	No	Yes	1.4%
147	Santa Cruz	Oeste-Rio	No	Yes	1.3%

Besides the fact that these districts have the most job positions in relation to the whole city, majority of them have metro and/or train stations. When faced with a fossil fuel crisis other districts may or may not benefit, depending on the presence of train or metro stations in these other districts. In addition to this, in case there is no compatibility of transportation modes within the districts, there may be a mobility impairment situation, if oil price is too high, or even if there is no availability of this resource.

8.3.1.2.1. IBGE Data Analysis

This section analyses the results presented in the map form, in section 8.3.1.1. The analysis follows an order based on the number of the figures, from lowest to highest. Each map regards one of the nine macrozones of Rio de Janeiro. However, the first analysis of this chapter is based on the vulnerability index and multiple linear regression results.

- **Figure 71: Vulnerability Index and multiple linear regression results analysis:**

Firstly, Figure 71 shows the vulnerability index of the entire city of Rio de Janeiro, plus the statistical evaluation of the resilience of urban mobility index of the current condition (H1) and the three threat scenarios (H2, H3 and H4). Through the multiple linear regression, this model shows that the independent variable (income, job positions, weighted average distance and accessibility to metro and/or train) has the explanatory power in relation to the resilience of urban mobility index when faced with each proposed threat scenarios.

The adjusted R square for the optimistic scenarios are approximately 88%, 91%, 93% and 90%, respectively for H1 (O), H2 (O), H3 (O) and H4 (O). The adjusted R square for the pessimistic are approximately 94%, 96%, 95% and 89%, respectively for H1 (P), H2 (P), H3 (P) and H4 (P).

For all of these cases, the P from F presents values lower then 0.05, which strengthens the fact that the model can possibly have a logical explanation, because it rejects the null hypothesis, i.e. the model has no explanatory power.

In the case of the P from T, in relation to the current situation (H1) for the optimistic scenario, which considers higher wage ranges, the presence of train and metro does not show a strong relation with the resilience level. Firstly, because of the consideration of the higher salaries, which lead to higher flexibility in modal choice and balances the effects of this choice with regard to the expenses. Furthermore, in the current situation, the prices of the different public transportation fares are not significantly different. These results also reflect the resilience level, which for the optimistic scenario, is at a low level of resilience in no district.

For the pessimistic scenario, in the current condition (H1), only the train variable has no influence, which can be explained, because the districts with train stations also coincide with the low-income conditions, in other words, these districts have a significant value of people with low-income levels. Therefore, the model, in a pessimistic scenario, tends to show that the presence of metro stations and higher income levels present higher resilience levels. Furthermore, the resilience level for this scenario shows that approximately 6% are within a low level of resilience and 65% are within a medium level of resilience.

In relation to the H2 threat, the optimistic scenario, all independent variables generate a level of influence on the resilience of urban mobility, because from P until T of these variables are lower than 0.05. There is an increase in the price of gasoline and oil-based public transportation, leading the difference of price between the public transportation modals to be more visible. For this reason, the use of metro and train shows improvement of resilience of urban mobility faced with the districts, which have no metro or train accessibility. Similar results occur in the H2 and H3 scenarios for the optimistic and pessimistic scenarios.

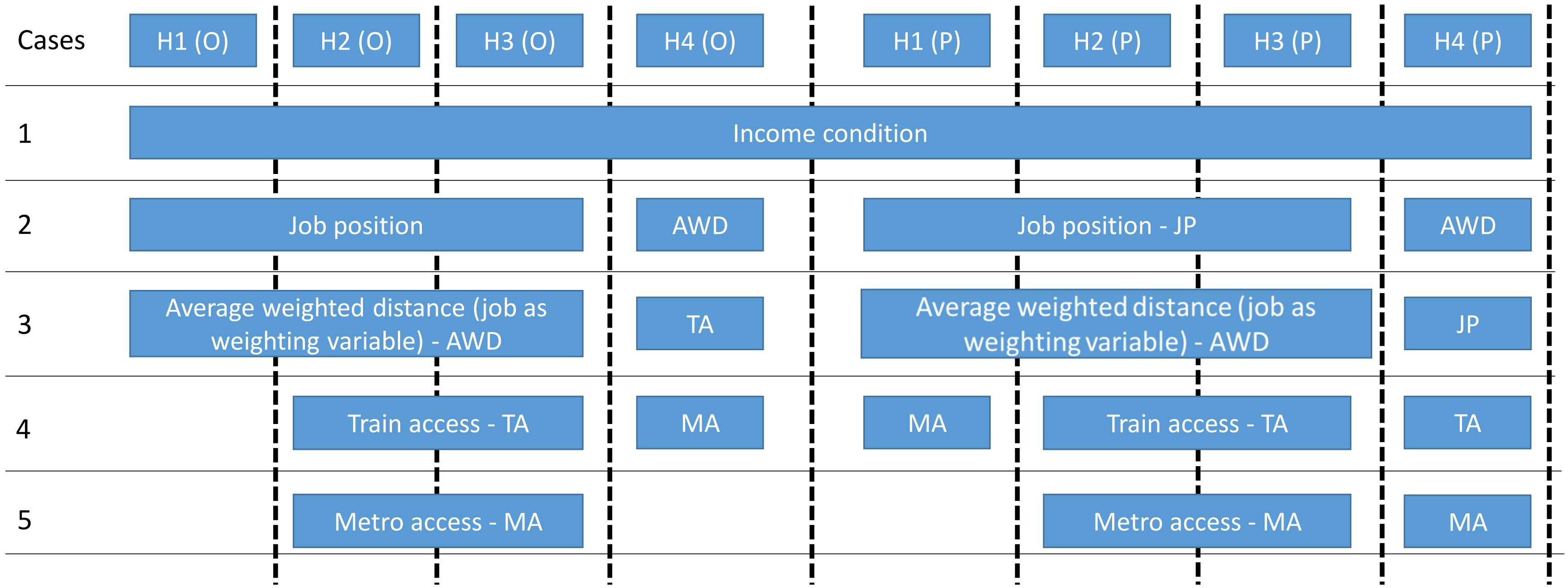
For the H4 scenario, which considers no availability of oil as fuel, and lack of oil-based public transportation, there are two different statistical results for the optimistic and pessimistic scenario. For the optimistic scenario, the job positions do not present a statistical significance because the P from T is higher than 0.05. This should be explained by the consideration of the higher salaries within the wage ranges, which means that people are still able to work out of the residence neighbourhoods, probably, if people do not have access to metro or train stations, while higher income people are able to use the car with alcohol as fuel. In the pessimistic scenario, the job positions seem to make a difference, because with lower wages, the sample faces a mobility impairment and being close to or even being in a neighbourhood with higher job availability can avoid the mobility impairment situation.

Figure 81 shows the order of influences of the independent variables, according to the value B of the statistical model applied. It is observed that income levels are the most influential data regarding the resilience of urban mobility, specifically to create conditions to adapt or persist during a fossil fuel threat. For Rio de Janeiro, which presents a reality with high-income variability, it may be a determinant factor to increase mobility opportunities, because beyond the geographical accessibility to places, there is also financial accessibility.

For the H2 and H3 threats (optimistic and pessimistic), job positions and average weighted distance (job as weighting variable) are, respectively in second and third positions in the level of influence. This means that increasing the number of job positions in the neighbourhoods may reduce the need to travel long distances to work, conditioning one to need and use less public transportation, in other words, walking or cycling. Train and metro access in the H2 and H3 scenarios (optimistic and pessimistic) are, respectively, in the fourth and fifth influential position. This is explainable by the fact that train covers a larger number of districts in the territory than the metro system. Approximately 40% (63 districts) of the districts in the city have access to train stations, while, approximately 20% (32 districts) have access to metro stations and 10% (16 districts) have access to both systems.

For the H4 threat scenario, which involves no gasoline and no oil-based public transportation (conventional buses or BRT), the average weighted distance is in second position of influence for both optimistic and pessimistic scenarios, pointing to the level of importance of using car as a mobility option and alcohol as the fuel option. This is because half of the city does not have easy access to a metro or train station. This points to two analysis approaches, districts that do not have metro or train, and people who want to go to these districts and even if they have access to train or metro, they cannot use these transport systems to reach these districts. For the optimistic scenario, further influential variables are, respectively, train and metro accessibility, for the same explanation used in the H2 and H3 cases. For the pessimistic scenario the further influential variables are, respectively, job positions, train and metro accessibility. In this case, the job positions show its importance because this scenario considers lower income levels, influencing the importance of working in the same or neighbourhood district.

Order of possible influence of independent variables considering the B results of the multiple linear regression model



Legend:
1 – Most influential variable
5 – Less influential variable

Figure 81: Order of possible influence of independent variables on the resilience of urban mobility based on the multiple linear regression model

Figure 82 presents the percentage of districts between each vulnerability level range in each macrozone. Focussing on those that are more vulnerable, between 0 and 2, it is possible to observe the marcrozones Centro, Sul, Jacarepagua, Norte, Barra-Recreio and Oeste-Rio. In case of Centro, over 60% of the districts are within 1 and 2 of the vulnerability index. In macrozone Sul, approximately 75% of the districts are within 0 and 2. In macrozone Jacarepagua, 100% of the districts are within 0 and 2. In macrozone Norte, approximately 54% of the districts are within 0 and 2. In macrozone Barra-Recreio, 100% of the districts are within 0 and 2. In macrozone Oeste-Rio, approximately 76% of the districts are within 0 and 2.

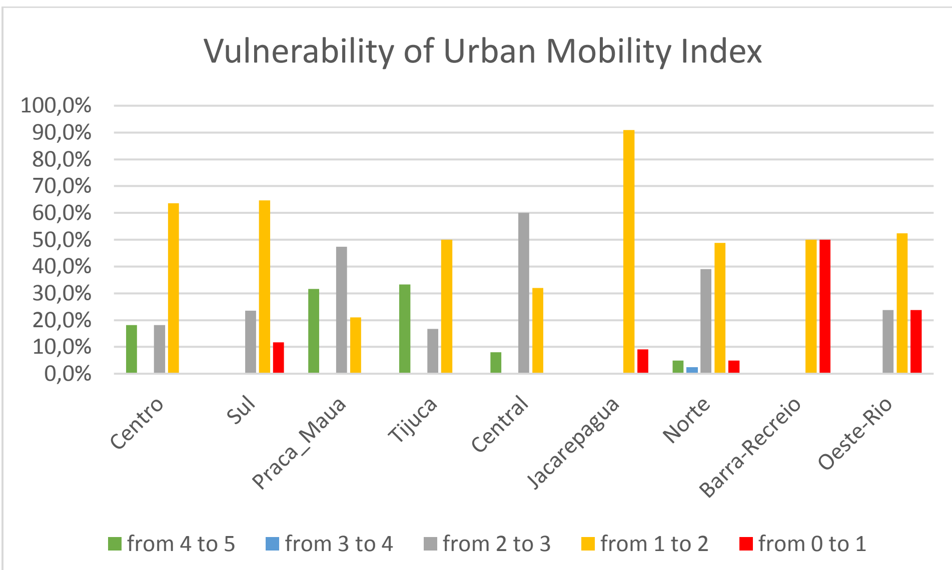


Figure 82: Percentage of districts between each vulnerability index range in each macrozone

In the analysis of the following figures, 67 until 75, analysis that is more specific is developed for each macrozone, considering the vulnerability index and the variables that composes of this index. Furthermore, the optimistic and pessimistic scenarios of the resilience of urban mobility are analysed.

- **Figure 72: Vulnerability and Index of Urban Resilience of the Macrozone "Centro" analysis**

Three districts in this macrozone have access to metro and train stations. Amongst these three, only the district Centro has direct access to these two systems, and the other two fall into the rule of access through distance and slope characteristics, which is based on equal or less than 2.5 km and both have an average slope acceptable for cycling. Only two districts that have access to metro stations and the others have no access to either metro or train stations.

In terms of wage conditions, there are four districts where more than 50% of the people have incomes higher than two minimum salaries. For the other districts, more than 50% of the population have incomes lower or equal to two minimum salaries, ranging approximately from 60% to 80%, respectively, Santa Teresa (Ref. 8) and Gamboa (Ref. 1). The other districts with the majority under two minimum salaries are between these values.

In terms of job positions, the district Centro stands out, in reason that it has approximately 27% of all job positions in the city of Rio de Janeiro. After Centro, the district with more job positions is Rio Comprido, with approximately 1% of the job positions in relation to the whole city. The other districts have less than 1%. However, this macrozone shows good distance levels in relation to places with most job positions, because they are near the district with most job positions (Centro).

The results of the resilience of urban mobility presented may have a strong influence by the distance, income condition and access to metro and train stations and because no district is within the most vulnerable index values, 0 and 1. In analysis, 40% of the districts of the macrozone are within 2 and 5 of the vulnerability index.

Table 35: Vulnerable districts in Macrozone Centro - Explanation

Districts	When do they fall into the low level of resilience (pessimistic)	Possible reasons
Gamboa	H4	Low income conditions, lack job positions (0.12% and 0.48%), no easy access to metro or train stations
Santo Cristo	H4	

Table 35 presents the vulnerable districts in macrozone Centro, where the level of threat and reasons show why they are vulnerable. Generally, in this macrozone, for the optimistic scenario, all neighbourhoods are out of the low level of resilience. For the pessimistic scenarios, the district, which can be highlighted with the worse conditions of adaptability and persistence are Gamboa and Santo Cristo, specifically for H3 and H4 threats. Firstly, approximately 80% of the population in these districts have income lower or those equal to two minimum salaries. Furthermore, although, these districts have good distance levels to Centro, with a high number of job positions, these districts have unfavourable slope conditions, which also make it difficult to access the metro and train stations in neighbourhood districts.

- **Figure 73: Vulnerability and Index of Urban Resilience of the Macrozone "Praca_Maua" analysis**

In this macrozone, six districts have access to metro and train stations, six have access only to train stations and three have access only to metro stations. In addition, four districts have no access to metro or train stations. The districts Maré (Ref. 31), Cidade Universitária (Ref. 32) and Caju (Ref. 48) have no access to train and metro stations, which leads to a stronger influence of the distance variable. While Complexo do Alemao (Ref. 35) does not have direct access to train or metro, this district has access to cable cars that lead the population of this district to Bonsucesso (Ref. 36), which has a train station. It is also observed that Complexo do Alemao has unfavourable cycling conditions, in order of the slope, conditions that make the population pay for the cable cars to access the train stations.

Regarding the wage conditions, only two districts from this macrozone have more than 50% of the population with income higher than two minimum salaries, Manguinhos (Ref. 40) and Maria da Graca (Ref. 43), which have the benefit of accessing metro and/or train stations. For the other districts, the percentage of population with income lower than two minimum salaries range approximately from 90% and 52%, respectively, Jacarezinho (Ref. 44) and Higienópolis (Ref. 39), both of which have access to metro and/or train stations.

In terms of job positions, the district with most job positions is Sao Cristovao (Ref. 45) with approximately 3% of job positions in relation to the whole city, followed by Bonsucesso (Ref. 36), with 2.5% of job positions. Ramos (Ref 33) and Manguinhos (Ref. 40) have approximately 1% of job positions and the other districts have less than 1% of job position in relation to the whole city. This means that in this macrozone, there are four districts with more than 1% of job positions in relation to the entire district. In relation to distance conditions, all of the districts show acceptable levels, mainly because this macrozone is the neighbour of the macrozone Centro, which presents the highest levels of job positions in the city, because of the district Centro.

Table 36: Vulnerable districts in Macrozone Praca_Maua – Explanation

Districts	When do they fall into the low level of resilience		Possible reasons
	Optimistic	Pessimistic	
Maré		H3 and H4	Low income conditions (64%), lack of job positions (0.25%), no easy access to metro or train stations
Cidade Universitária		H4	Low income conditions (58%), lack of job positions (0.65%), no easy access to metro or train stations
Complexo do Alemao	H4	H1, H2, H3 and H4	Low income conditions (89%), lack of job positions (0.00%) and no easy access to metro or train stations
Inhaúma		H4	Low income conditions (70%), lack of job positions (0.39%) and no access to train station
Jacarezinho		H1, H2, H3 and H4	Low income conditions (91%), lack of job positions (0.00%) and no access to metro station
Caju		H2, H3 and H4	Low income conditions (85%), lack of job positions (0.25%) and no easy access to metro or train stations

Table 36 presents the vulnerable districts in macrozone Praca_Maua, where the level of threat and reasons show why they are vulnerable. In relation to the resilience levels, for the optimistic scenario, it is possible to highlight the district Complexo do Alemao (Ref. 35), which in the H4 scenario falls into low level of resilience. For the pessimistic scenario, it is possible to highlight the districts Maré, Cidade Universitária, Complexo do Alemao, Inhaúma, Jacarezinho and Caju, in which two of them fall into the low level of resilience in the current conditions (H1), affecting the persistence of maintaining the same mobility and social patterns in possible fossil fuel threat scenarios.

- **Figure 74: Vulnerability and Index of Urban Resilience of the Macrozone "Central" analysis**

In this macrozone, there are two districts with access to both train and metro stations and 15 districts have access to train stations. Eight districts have no access to metro or train stations. This macrozone presents unfavourable slope conditions, which generates difficulty of access to metro or train station by bicycle.

In relation to the income conditions, in six districts more than 50% of the population have income higher than two minimum salaries [Marechal Hermes (Ref. 55) Cachambi (Ref. 66), Todos os Santos (Ref. 69), Rocha (Ref. 71), Méier (Ref. 72) and Riachuelo (Ref. 74)]. The other 19 districts have a majority living with less than two minimum salaries. The districts with majority living with less than two minimum salaries, the statistic varies from 91% to 51%, respectively, Mangueira (Ref. 77) and Abolicao (Ref. 65). In addition, the district Mangueira has access to train stations, while Abolicao does not have access to either metro or train.

In relation to job positions, one district in this macrozone has more than 1% of job positions in relation to the whole city, which is Lins de Vasconcelos (Ref. 79) with 1.01%. The other districts have less than 1% of the job positions in relation to the city. Lins de Vasconcelos has no access to train or metro stations, mainly because of the slope condition. This situation makes the accessibility to this district difficult. In terms of the average weighted distance (based on job positions), all districts present acceptable distance levels because of the proximity to the macrozones, Centro and Praca_Maua.

Table 37: Vulnerable districts in Macrozone Central - Explanation

Districts	When do they fall into the low level of resilience (pessimistic)	Possible reasons
Osvaldo Cruz	H2, H3 and H4	Low income conditions (78%), lack of job positions (0.16%) and no access to metro stations
Cavalcanti	H4	Low income conditions (71%), lack of job positions (0.06%) and no access to metro stations
Engenheiro Leal	H2, H3 and H4	Low income conditions (71%), lack job of positions (0.03%) and no access to metro or train stations
Campinho	H4	Low income conditions (52%), lack job of positions (0.11%) and no access to metro or train stations
Abolicao	H4	Low income conditions (51%), lack job of positions (0.12%) and no access to metro or train stations
Encantado	H4	Low income conditions (54%), lack job of positions (0.18%) and no access to metro or train stations
Mangueira	H2, H3 and H4	Low income conditions (91%), lack job of positions (0.68%) and no access to metro stations
Agua Santa	H4	Low income conditions (53%), lack job of positions (0.09%) and no access to metro or train stations
Lins de Vasconcelos	H4	Low income conditions (60%), lack job of positions (1.01%) and no access to metro or train stations

Table 37 presents the vulnerable districts in the macrozone Central, where the level of threat and reasons show why they are vulnerable. In relation to resilience levels, for the optimistic scenario, no district falls into the low level of resilience, which reflects the consideration of the optimistic income condition, favourable average weighted distance and the majority of districts have access to train stations. For the pessimistic scenarios, nine districts fall into the low level of resilience, in diverse threat situations. These districts are Osvaldo Cruz (Ref. 58), Cavalcanti (Ref. 59), Engenheiro Leal (Ref. 60), Campinho (Ref. 64), Abolicao (Ref. 65), Encantado (Ref. 70), Mangueira (Ref. 77), Agua Santa (Ref. 78) and Lins de Vasconcelos (Ref. 79).

- **Figure 75: Vulnerability and Index of Urban Resilience of the Macrozone “Sul” analysis**

In this macrozone, there are four districts with access to metro stations and no district has access to train stations. Districts with no access to train or metro stations are 13. It is possible to observe that this macrozone has unfavourable slope conditions. Furthermore, in this macrozone the population with lower income levels, mainly those who reside in slums (“*favelas*”), are commonly located in the mountainous areas. This reflects the difficulty of cycling or walking to a metro station, even if this population stays near to a metro station.

In terms of income conditions, districts that have more than 50% of the population with an income higher than two minimum salaries are 13. Whereas four districts in this macrozone have more than 50% of the population with income lower than two minimum salaries. Both Rocinha (Ref. 28) and Vidigal (Ref. 29) are, in majority, slum areas and have no access to metro or train stations.

In relation to the job positions, districts that have more than 1% of job positions in relation to the entire city are four, which are Laranjeiras (Ref. 14) with 1.02%, Botafogo (Ref. 22) with 3.69%, Copacabana (Ref. 21) with 2.16% and Ipanema (Ref. 26) with 1.21%. Laranjeiras is the only district that does not have access to a metro station, due to the slope conditions. The average weighted distance for all districts in this macrozone presents acceptable values, in order of the proximity to the macrozone Centro and the number of job positions in the presented four districts.

Table 38: Vulnerable districts in Macrozone Sul – Explanation

Districts	When do they fall into the low level of resilience		Possible reasons
	Optimistic	Pessimistic	
Alto da Boa Vista		H4	Low income conditions (56%), lack of job positions (0.07%), no easy access to metro or train stations
Leme		H4	Low income conditions (57%), lack of job positions (0.12%), no easy access to metro or train stations
Rocinha	H4	H1, H2, H3 and H4	Low income conditions (88%), lack of job positions (0.00%), no easy access to metro or train stations
Vidigal	H4	H2, H3 and H4	Low income conditions (81%), lack of job positions (0.07%), no easy access to metro or train stations

Table 38 presents the vulnerable districts in macrozone Sul, where the level of threat and reasons show why they are vulnerable. The level of the resilience of urban mobility for the optimistic scenarios shows two districts that fall into the low level of resilience at the H4 threat, Rocinha and Vidigal. For the pessimistic scenario, four districts fall into the low level of resilience in different threat approaches. They are Alto da Boa Vista (Ref. 15), Leme (Ref. 22), Rocinha and Vidigal, which have a majority of population with low-income levels and have difficulty in accessing metro stations, due to the slope and distance conditions.

- **Figure 76: Vulnerability and Index of Urban Resilience of the Macrozone "Tijuca" analysis**

Two districts that have access to both train and metro stations are Praca da Bandeira (Ref. 49) and Maracana (Ref. 51). Tijuca (Ref. 52) is the district that has access only to metro stations. There are three districts that present no complicated access to train or metro stations, which are Vila Isabel (Ref. 50), Grajau (Ref. 53) and Andarai (Ref. 54).

The income information of the districts in this macrozone shows that Maracana (Ref. 51) has more than 50% of the population earning less than two minimum salaries, which specifically, is 87%. In the other districts, majority of population earns more than two minimum salaries.

In terms of job positions, only one district has more than 1% of job position in relation to the entire city of Rio de Janeiro, which is Tijuca (Ref. 52) with 3.26%. The other districts in this macrozone have less than 1% of the job positions of the city. In relation to the average weighted distance, all districts show acceptable levels of distance to the districts with more job positions.

Table 39: Vulnerable districts in Macrozone Tijuca – Explanation

Districts	When do they fall into the low level of resilience (pessimistic)	Possible reasons
Maracana	H2, H3 and H4	Low income conditions (87%) and lack of job positions (0.08%)

Table 39 presents the vulnerable districts in macrozone Tijuca, where the level of threat and reasons show why they are vulnerable. The indexes of the resilience of urban mobility of this macrozone shows that for the optimistic approach, no district stands into the low level of resilience when facing the presented threats. For the pessimistic scenario, Maracana falls into the low level of resilience from the H2 threat. Although this district has access to metro and train stations, it presents a high number of population living with income equal or less than two minimum salaries.

- **Figure 77: Vulnerability and Index of Urban Resilience of the Macrozone "Barra-Recreio" analysis**

No district has access to metro or train stations in this macrozone. In relation to the income levels, Barra da Tijuca (Ref. 136), Recreio dos Bandeirantes (Ref. 137) and Joá (Ref. 138) have more than 50% of the population with income higher than two minimum salaries. The other districts present a majority living under low-income conditions.

In terms of job positions, Barra da Tijuca (Ref. 136), with 6.29%, has more than 1% of job position in relation to the entire city. The other districts have less than 1% of the job positions. In relation to the average weighted distance, four districts, Centro, Praca_Maua, Norte and Central, present values 2 or 3 times higher than in districts in the macrozone, in other words, they present unfavourable accessibility to districts with more job positions. These four districts are Vargem Grande (Ref. 132), Vargem Pequena (Ref. 134), Recreio dos Bandeirantes (Ref. 137) and Grumari (Ref. 139).

Table 40: Vulnerable districts in Macrozone Barra-Recreio – Explanation

Districts	When do they fall into the low level of resilience		Possible reasons
	Optimistic	Pessimistic	
Vargem Grande	H4	H2, H3 and H4	Low income conditions (69%), lack of job positions (0.19%) and distance conditions (39.51 km), no access to metro or train stations
Camorim		H4	Low income conditions (52%), lack of job positions (0.01%) and no access to metro or train stations
Vargem Pequena	H4	H2, H3 and H4	Low income conditions (74%), lack of job positions (0.04%), distance conditions (32.79 km) and no access to metro or train stations
Itanhangá	H4	H3 and H4	Low income conditions (66%), lack of job positions (0.08%) and no access to metro or train stations
Grumari	H3 and H4	H1, H2, H3 and H4	Low income conditions (99%), lack of job positions (0.00%), distance conditions (41.30 km) and no access to metro or train stations

Table 40 presents the vulnerable districts in the macrozone Barra-Recreio, where the level of threat and reasons show why they are vulnerable. In relation to the levels of resilience of urban mobility, there are four districts, which in the optimistic approach, falls into the low level of resilience, which are Vargem Grande (Ref. 132), Vargem Pequena (Ref. 134), Itanhangá (Ref. 135) and Grumari (Ref. 139). For the pessimistic approach, beyond those of the optimistic approach, also Camorim (Ref. 133) have resilience index in the low level.

- **Figure 78: Vulnerability and Index of Urban Resilience of the Macrozone "Norte" analysis**

In this macrozone, three districts that have access to both metro and train stations are Pavuna (Ref. 101), Coelho Neto (Ref. 118) and Barros Filho (Ref.121). There are six districts that have access to only metro stations and 12 that have access only to train stations. The other 20 does not have access to any of the systems, mainly because of the unfavourable slope conditions.

In relation to the income levels, 33 districts in this macrozone has majority of population with income lower than two minimum salaries. While eight districts have majority of population with income higher than this, which are Portuguesa (Ref. 95), Cocota (Ref. 98), Jardim Guanabara (Ref. 103), Praia da Bandeira (Ref. 106), Zumbi (Ref. 116), Ribeira (Ref. 117), Vista Alegre (Ref. 122) and Vila da Penha (Ref. 126). Most of these districts do not have access to metro or train stations, more specifically, six of the eight.

In terms of job positions, only one of the 41 districts has more than 1% of the job positions in relation to the entire city of Rio de Janeiro, which is Penha (Ref. 115) with 1.07%, which has access to only the metro station. All of the districts of this macrozone present acceptable average weighted distance values because of the proximity to the macrozones, Centro and Praca_Maua.

Table 41: Vulnerable districts in Macrozone Norte – Explanation

Districts	When do they fall into the low level of resilience		Possible reasons
	Optimistic	Pessimistic	
Freguesia (Ilha)		H4	Low income conditions (57%), lack of job positions (0.09%) and no access to metro or train stations
Bancários		H3 and H4	Low income conditions (62%), lack of job positions (0.89%) and no access to metro or train stations
Galeao		H3 and H4	Low income conditions (68%), lack of job positions (0.01%) and no access to metro or train stations
Tauá		H3 and H4	Low income conditions (65%), lack of job positions (0.24%) and no access to metro or train stations
Portuguesa		H4	Lack of job positions (0.11%) and no access to metro or train stations
Moneró		H4	Low income conditions (57%), lack of job positions (0.58%) and no access to metro or train stations
Vigário Geral		H2, H3 and H4	Low income conditions (79%), lack of job positions (0.89%) and no access to metro stations
Cocotá		H4	Lack of job positions (0.04%) and no access to metro or train stations
Jardim Carioca		H3 and H4	Low income conditions (60%), lack of job positions (0.10%) and no access to metro or train stations
Cordovil		H3 and H4	Low income conditions (74%), lack of job positions (0.21%) and no access to metro stations
Parada de Lucas		H2, H3 and H4	Low income conditions (81%), lack of job positions (0.17%) and no access to metro stations
Parque Columbia	H4	H2, H3 and H4	Low income conditions (75%), lack of job positions (0.00%) and no access to metro or train stations
Praia da Bandeira		H4	Lack of job positions (0.03%) and no access to metro or train stations
Cacuia		H3 and H4	Low income conditions (58%), lack of job positions (0.12%) and no access to metro or train stations
Anchieta	H4	H2, H3 and H4	Low income conditions (72%), lack of job positions (0.15%) and no access to metro or train stations
Acari		H1, H2, H3 and H4	Low income conditions (90%), lack job positions (0.06%) and no access to train stations
Pitangueiras	H4	H2, H3 and H4	Low income conditions (70%), lack of job positions (0.01%) and no access to train or metro stations
Costa Barros		H1, H2, H3 and H4	Low income conditions (87%), lack of job positions (0.01%) and no access to train stations
Guadalupe		H3 and H4	Low income conditions (68%), lack of job positions (0.18%) and no access to train or metro stations
Barros Filho		H1, H2, H3 and H4	Low income conditions (85%) and lack of job positions (0.18%)
Vista Alegre		H4	lack job positions (0.08%) and no access to train stations
Ricardo de Albuquerque		H3 and H4	Low income conditions (73%), lack of job positions (0.06%) and no access to metro stations
Colégio		H3 and H4	Low income conditions (74%), lack of job positions (0.12%) and no access to train stations
Honório Gurgel		H4	Low income conditions (72%), lack of job positions (0.02%) and no access to metro stations
Vila Kosmos		H4	Low income conditions (59%), lack of job positions (0.63%) and no access to metro or train stations
Vicente de Carvalho		H3 and H4	Low income conditions (72%), lack of job positions (0.19%) and no access to train stations
Vaz Lobo		H2, H3 and H4	Low income conditions (70%), lack of job positions (0.08%) and no access to train or metro stations
Turiacu		H2, H3 and H4	Low income conditions (69%), lack of job positions (0.05%) and no access to train or metro stations

Table 41 presents the vulnerable districts in macrozone Norte, where the level of threat and reasons show why they are vulnerable. In relation to the resilience of urban mobility faced with the possible threats, for the optimistic approach, three districts that fall into the low level of resilience, which are Parque Columbia (Ref. 105), Anchieta (Ref. 110) and Pitangueiras (Ref. 112). None of them has access to metro or train stations. For the pessimistic approach, 28 districts fall into the low level of resilience, mainly because of the low-income condition.

- **Figure 79: Vulnerability and Index of Urban Resilience of the Macrozone "Oeste-Rio" analysis**

In this macrozone, 14 of the 21 districts have access to train stations. None of the districts has access to metro stations. Seven districts have no access to train stations. In this macrozone, the access to train stations from the districts that have no access are mainly influenced by the size of the districts and consequently, the distance within the districts.

The income conditions' data show that most of population in the 19 districts have income lower than two minimum salaries. The majority in the other two districts have income higher than two minimum salaries, and furthermore, they have no access to train stations, Campo dos Afonsos (Ref. 150) and Jardim Sulacap (Ref. 151).

In terms of job positions, Campo Grande (Ref. 140) with 6.09%, Bangu (Ref. 141) with 1.41% and Santa Cruz (Ref. 147) with 1.32% are the three districts with more than 1% of the job positions in relation to the entire city of Rio de Janeiro. In relation to the average weighted distance, there are 11 districts with value 2 or more times higher than districts in macrozone Centro, which does not have access to train stations, in specific, Guaratiba (Ref. 155), Sepetiba (Ref. 156), Pedra de Guaratiba (Ref. 157), Barra de Guaratiba (Ref. 158) and Gericinó (Ref. 160). Furthermore, these 11 districts with unfavourable distance to places with more job positions present low-income patterns.

Table 42: Vulnerable districts in Macrozone Oeste-Rio – Explanation

Districts	When do they fall into the low level of resilience		Possible reasons
	Optimistic	Pessimistic	
Bangu		H4	Low income conditions (71%) and no access to metro stations
Realengo		H4	Low income conditions (69%), lack of job positions (0.69%) and no access to metro stations
Paciencia		H4	Low income conditions (68%), lack of job positions (0.16%), distance (44.98 km) and no access to metro stations
Santíssimo		H3 and H4	Low income conditions (73%), lack of job positions (0.15%) and no access to metro stations
Santa Cruz		H2, H3 and H4	Low income conditions (78%), distance (50.76 km) and no access to metro stations
Magalhaes Bastos		H1, H2, H3 and H4	Low income conditions (85%), lack of job positions (0.03%) and no access to metro stations
Senador Camará		H2, H3 and H4	Low income conditions (77%), lack of job positions (0.11%) and no access to metro stations
Senador Vasconcelos		H4	Low income conditions (68%), lack of job positions (0.16%), distance (32.92 km) and no access to metro stations
Cosmos		H2, H3 and H4	Low income conditions (76%), lack of job positions (0.10%), distance (41.67 km) and no access to metro stations
Inhoaíba		H2, H3 and H4	Low income conditions (78%), lack of job positions (0.21%), distance (39.55 km) and no access to metro stations
Guaratiba	H4	H2, H3 and H4	Low income conditions (78%), lack of job positions (0.17%), distance (45.98 km) and no access to metro stations
Sepetiba	H4	H2, H3 and H4	Low income conditions (79%), lack of job positions (0.07%), distance (52.10 km) and no access to metro or train stations
Pedra de Guaratiba	H4	H3 and H4	Low income conditions (64%), lack of job positions (0.03%), distance (48.16 km) and no access to metro or train stations
Barra de Guaratiba	H4	H3 and H4	Low income conditions (63%), lack of job positions (0.04%), distance (44.34 km) and no access to metro or train stations
Deodoro		H2, H3 and H4	Low income conditions (74%), lack of job positions (0.04%) and no access to metro stations
Gericinó	H4	H1, H2, H3 and H4	Low income conditions (85%), lack of job positions (0.00%), distance (32.82 km) and no access to metro or train stations

Table 42 presents the vulnerable districts in macrozone Oeste-Rio, where the level of threat and reasons show why they are vulnerable. According to the resilience results, the optimistic approach shows that five districts fall into the low level of resilience in the H4 threat level, which are Guaratiba (Ref. 155), Sepetiba (Ref. 156), Pedra de Guaratiba (Ref. 157), Barra de Guaratiba (Ref. 158) and Gericinó (Ref. 160). The pessimistic approach shows that 16 districts fall into the low level of resilience when facing the proposed threats.

- **Figure 80: Vulnerability and Index of Urban Resilience of the Macrozone "Jacarepagua" analysis**

No district in this macrozone has access to metro or train stations, mainly because of distance to districts with metro or train stations. In relation to income conditions, majority of the population in the seven districts in this macrozone have income lower than two minimum salaries. The other four, however, have a contrary situation, which are Vila Valqueire (Ref. 80), Freguesia (Ref. 84), Pechincha (Ref. 85) and Anil (Ref. 88).

In terms of job positions, Taquara (Ref. 83) with 1.27% is one district in this macrozone with more than 1% of job positions in relation to the entire city. The other 10 districts have less than 1% of job positions. The average weighted distance based on job positions shows that the districts of this macrozone has favourable values in relation to the distance to places with more job positions.

Table 43: Vulnerable districts in Macrozone Jacarepagua - Explanation

Districts	When do they fall into the low level of resilience		Possible reasons
	Optimistic	Pessimistic	
Praca Seca		H4	Low income conditions (56%), lack of job positions (0.17%) and no access to metro or train stations
Tanque		H3 and H4	Low income conditions (60%), lack of job positions (0.23%) and no access to metro or train stations
Taquara		H4	Low income conditions (51%) and no access to metro or train stations
Curicica		H3 and H4	Low income conditions (64%), lack of job positions (0.50%) and no access to metro or train stations
Cidade de Deus	H4	H2, H3 and H4	Low income conditions (83%), lack of job positions (0.03%) and no access to metro or train stations
Jacarepagua		H2, H3 and H4	Low income conditions (71%), lack of job positions (0.78%) and no access to metro or train stations
Gardenia Azul		H2, H3 and H4	Low income conditions (74%), lack of job positions (0.09%) and no access to metro or train stations

Table 43 presents the vulnerable districts in macrozone Jacarepagua, where the level of threat and reasons show why they are vulnerable. The resilience results show that for the optimistic approach, only Cidade de Deus (Ref. 87) falls into the low level of resilience, in the H4 threat. For the pessimistic approach, seven districts fall into the low level of resilience in different threat situations.

8.3.2. Qualitative Results

The qualitative results deal with the data gathered in fieldwork during the period of October 5, 2015 until December 27, 2015 (date of the last responded questionnaire). Based on the origin (residence) of the interviewees, the results were organised in groups, following the macrozones used in the previous quantitative analysis. This section analyses, firstly, the general information of the fieldwork data, then the analyses are divided according to the type of transportation users, private, public and both transportation users.

Table 44 shows the size of the samples per macrozone and transportation type (public, private and both transportation users). According to the last modal choice study (report) of the metropolitan area of Rio de Janeiro (Governo do Estado do Rio de Janeiro, 2010), it was found that approximately 46.5% of the trips are made by public transportation, 16.5% by private transportation and 37% by non-motorised transportation. The collected data in fieldwork shows that approximately 68.5% of the interviewees use public transportation, 19.2% use both public and private and 12.1% use private transportation. The fieldwork shows similarities with the values of the commented report in terms of the majority using public transportation.

Table 44: Sample size per Macrozone and Transportation Type

Type of Transportation Mode	Sul	Barra-Recreio	Central	Norte	Oeste-Rio	Jacarepagua	Tijuca	Praca_Maua	Centro	Total
Private transportation users	4	4	8	14	2	2	6	2	3	45
Public transportation users	43	3	31	54	21	19	38	29	15	253
Both transportation users	15	10	9	9	9	8	6	4	1	71
Total	62	17	48	77	32	29	50	35	19	369

Figure 83 shows the origin information by macrozone and type of transportation, data in this figure is presented in percentage values, in relation to the whole sample for each type of transportation use. For example, the percentage of people who use public transportation travelling to macrozone Sul is divided by the total number of people who use public transportation. Based on this logic, the values show the percentage of people travelling to a certain macrozone in a certain type of transportation, based on the total value of trips for each type of transportation use, not on the total number of people going to a certain macrozone. This logic is also applied to the destination analysis in Figure 84.

In relation to the origin of travels, in the macrozone Sul, the percentual of both and public transportation users are higher in comparison to private transportation users, which may be explained by the accessibility to metro and bus systems and also a flexibility in the attitude of changing transportation mode use face to certain needs. Besides this accessibility, this macrozone has favourable distance to districts with more job positions, within its own and neighbourhood macrozones, which allows the use of private transportation, leading to lower expenses with gasoline or alcohol as fuel.

In the macrozone Barra-Recreio, the data shows that the use of both and private transportation users are higher than public transportation use. This could be explained by the limitation of public transportation use, specifically, only conventional buses and BRT. Furthermore, the flexibility of people to use private or public transportation leads to higher adaptability attitude. In other words, these people may be more flexible in changing transportation mode according to price increase of fuel or public transportation fare.

In the macrozone Central, the use of private transportation is higher in relation to use of private transportation in the entire city and this may be a result of the difficulty to access metro or train stations in the districts of this macrozone. However, there are still significant results of both and public transportation users, which may be related to income condition and favourable distance to the destination district.

In the macrozone Norte, there are a higher percentage of private transportation users, followed by a high level of public transportation use. These values can be explained by the accessibility to train and metro stations, income conditions and favourable distance to work. However, there are some districts in this macrozone that have a complicated access to metro or train stations, for slope or/and distance reasons.

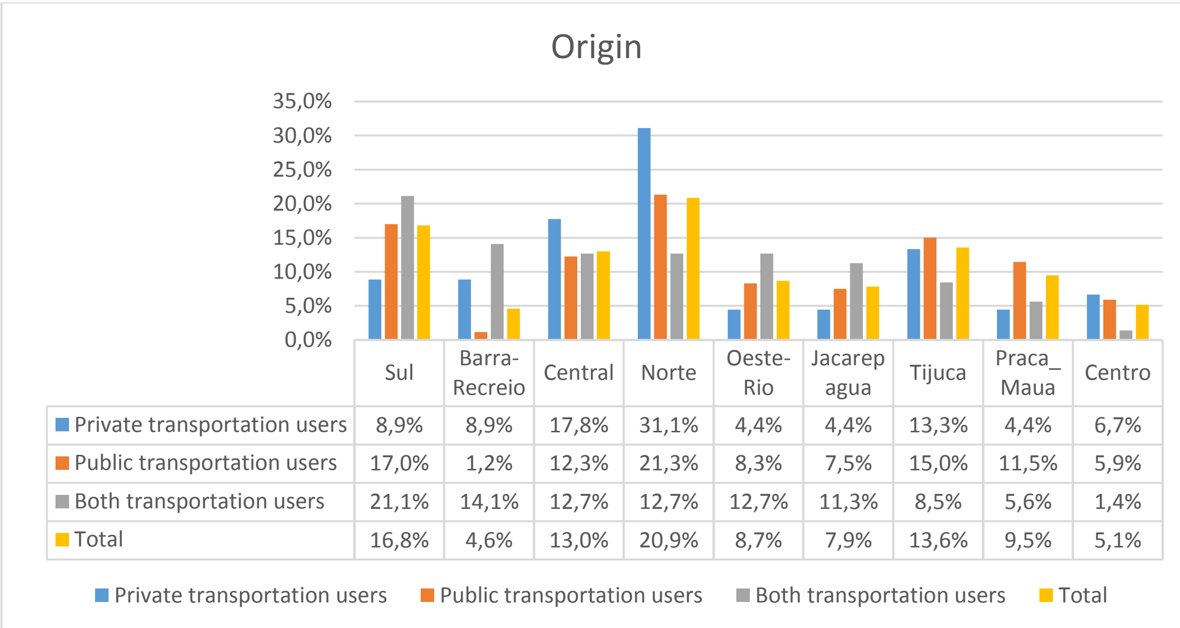
The macrozone Oeste-Rio shows that of all the values of those who are flexible to use both transportation types, 12.7% are from this macrozone, which is the highest percentage in relation to the public (second highest) and private transportation use (third). The data may reflect the accessibility to train stations in some districts, but also the low reliability on the public transportation system, leading to the flexibility to use private or public transportation systems. Furthermore, respondents in this macrozone may work in a favourable distance for private transportation use.

The macrozone Jacarepagua have similar results as the macrozone Oeste-Rio. However, in this macrozone, there is no access to metro or train stations. Furthermore, there is a higher percentual of people who are living with low-income conditions.

In the macrozone Tijuca, the use of public transportation is more significant, followed by private transportation use and both. This result may be related to favourable distance to districts with more job positions, the accessibility in some districts to metro and/or train stations and a majority of citizens living with income higher than two minimum salaries.

In macrozone Praca_Maua, the use of public transportation is more dominant than the public or both transportation users. These values may be explained by the accessibility of most districts to train and/or metro stations.

In macrozone Centro, the private transportation is higher, but close to public transportation users. This macrozone has partial accessibility to metro and train stations. Besides this, the people of this district may be travelling to districts where there is no access to metro or train stations. Therefore, assuming that the sample of this district is travelling to a favourable distance, it leads to the use of private transportation if affordable by the person or by the public, when private transportation is not affordable.



	Sul	Barra-Recreio	Central	Norte	Oeste-Rio	Jacarepagua	Tijuca	Praca_Maua	Centro
Private transportation users	8,9%	8,9%	17,8%	31,1%	4,4%	4,4%	13,3%	4,4%	6,7%
Public transportation users	17,0%	1,2%	12,3%	21,3%	8,3%	7,5%	15,0%	11,5%	5,9%
Both transportation users	21,1%	14,1%	12,7%	12,7%	12,7%	11,3%	8,5%	5,6%	1,4%
Total	16,8%	4,6%	13,0%	20,9%	8,7%	7,9%	13,6%	9,5%	5,1%

Figure 83: Origin Information by Macrozone and Type of Transportation

Figure 84 follows the same logic as in Figure 83 because it shows the percentage of trips through private, public or both transportation modes to each macrozone (destination). In relation to all private transportation trips, 37.8% go to macrozone Praca_Maua, followed by Norte (13.3%), Sul (11.1%), Barra-Recreio (11.1%), Centro (8.9%), Central (6.7%), Oeste-Rio (6.7%), Jacarepagua (2.2%) and Tijuca (2.2%).

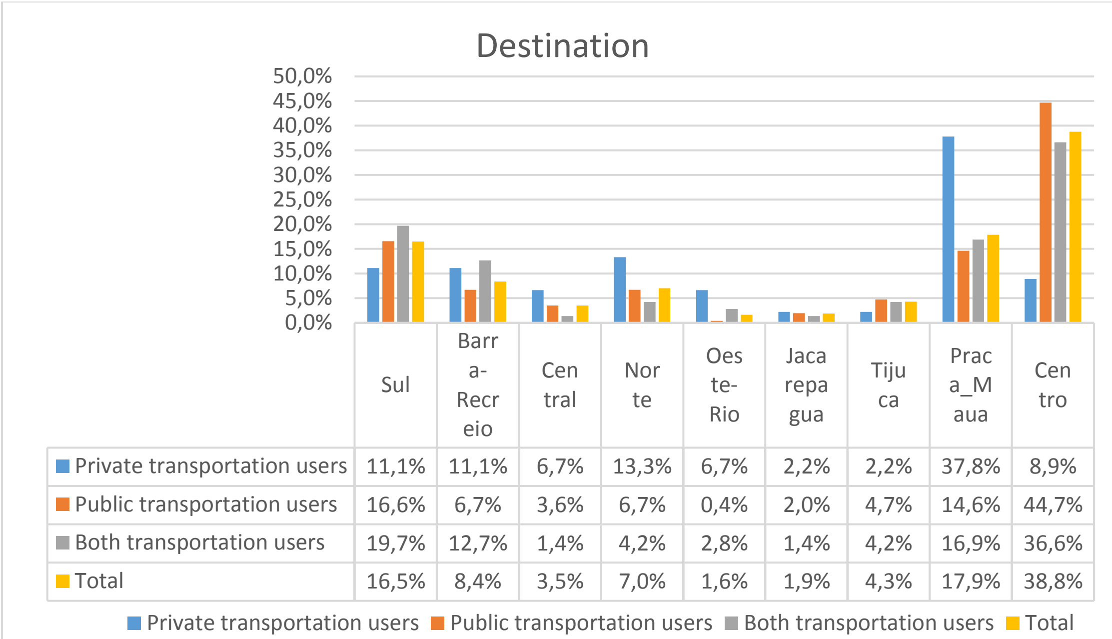
The distribution of trips of public transportation users who travel to macrozone Centro are 44%, followed by Sul (16.6%), Praca_Maua (14.6%), Barra-Recreio (6.7%), Norte (6.7%), Tijuca (4.7%), Central (3.6%), Jacarepagua (2.0%) and Oeste-Rio (0.4%).

The distribution of trips of both transportation users who travel to macrozone Centro are 36%, followed by Sul (19.7%), Praca_Maua (16.9%), Barra-Recreio (12.7%), Norte (4.2%), Tijuca (4.2%), Oeste-Rio (2.8%), Central (1.4%) and Jacarepagua (1.4%).

These results show that the weighted average based on job positions in one of the stages of the measurement of the resilience of urban mobility makes sense. This is because the city of Rio de Janeiro has a concentration of job positions in the Central Business District (CBD) area, which can be, in this case, macrozone Centro and consequently, an attraction of trips in this macrozone and the surroundings.

Barra-Recreio is a macrozone with characteristics different from the others. Specifically, the district Barra da Tijuca in this macrozone, which is the epicentre of urban growth in this region with currently 6.29% of job positions, initiated to be included in the urban network of Rio de Janeiro in the 1970s (Souza, 2006). Furthermore, the government of Rio de Janeiro hired an urbanist from Brasília (capital of Brazil) to develop an urbanisation plan in this area (Souza, 2006). Barra da Tijuca is a district that reflects the process of income concentration, a significant participation of the real estate market and other private sectors actions (Ferreira, 2009). In recent years, a report was developed by a group of scholars and research groups that presented a significant part of infrastructural investments of the municipality of Rio de Janeiro that are concentrated in the macrozones Sul and Barra-Recreio, in order of the 2014 World Cup and 2016 Olympic Games (Comitê Popular Rio da Copa e das Olimpíadas, 2013).

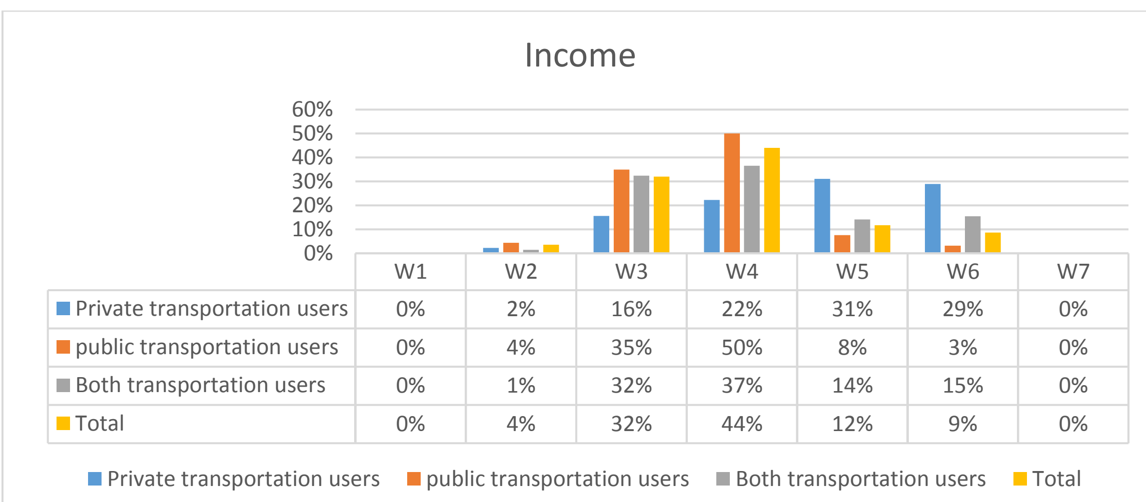
Different from other parts of the city, Barra da Tijuca and the surrounding districts were intentionally planned to attract high- and middle-income families. Furthermore, it attracts large business complexes. The accessibility to this was built mainly based on three- or four-lane highways, stimulating the use of private transportation.



	Sul	Barr a-Recr eio	Cen tral	Nor te	Oes te-Rio	Jaca repa gua	Tiju ca	Prac a_M aua	Cen tro
Private transportation users	11,1%	11,1%	6,7%	13,3%	6,7%	2,2%	2,2%	37,8%	8,9%
Public transportation users	16,6%	6,7%	3,6%	6,7%	0,4%	2,0%	4,7%	14,6%	44,7%
Both transportation users	19,7%	12,7%	1,4%	4,2%	2,8%	1,4%	4,2%	16,9%	36,6%
Total	16,5%	8,4%	3,5%	7,0%	1,6%	1,9%	4,3%	17,9%	38,8%

Figure 84: Destination Information by Macrozone and Type of Transportation

Figure 85 presents the percentage of each type of transportation users who have income between each of the ranges (W1 means lower income and W7 higher income). The values from this figure show that public transportation users tend to have a lower income, while private transportation users tend to have a higher income. The values of transportation users of both are in between the public and private transportation users.



	W1	W2	W3	W4	W5	W6	W7
Private transportation users	0%	2%	16%	22%	31%	29%	0%
public transportation users	0%	4%	35%	50%	8%	3%	0%
Both transportation users	0%	1%	32%	37%	14%	15%	0%
Total	0%	4%	32%	44%	12%	9%	0%

Figure 85: Percentage of people between each Income range by transportation type

8.3.2.1. Private Transportation User's Analysis

This section analyses approximately 12% of the sample, which can be characterised as the group of people who avoid public transportation and may have strong tendency in using private transportation when faced with possible fossil fuel threats.

Table 45, Table 46 and Table 47 presents the synthesised information of the data collected from the private transportation users. The intention is to codify every variable to generate the persistence (Table 45) and adaptability (Table 46 and Table 47) index. Furthermore, the analysis is processed by the macrozone.

In the **macrozone Sul**, it can be observed that destination, fuel type, transportation cover and effects of transportation cost are the variables that can lead the interviewees of this macrozone to stop using private transportation when faced with a sudden increase in the price of petroleum (Table 45). In the cited order, the variables are explained. In relation to the destination, only 25% of the respondents work in a neighbourhood macrozone and there is no respondent working in the macrozone from their residence.

The fuel type variable shows that 100% of the respondents use gasoline as fuel, while 50% uses alcohol. In other words, 50% varies the fuel use, between gasoline and alcohol.

Regarding the transport cover, it is observed that 75% of respondents from macrozone Sul have to cover transportation cost from their own salary, partially or totally, while 25% has to cover transportation cost partially and 50% entirely.

The information of the effect of current transportation cost on personal expenses shows that between 50% and 75%, the respondents are already sacrificing expenses with basic needs from group "a" and between 25% and 50%, they are already sacrificing expenses from group "b" and "c", respectively, leisure and others (b) and savings (c).

Table 45: Variables of the Persistence Stage of Analysis of the Qualitative Approach – Private Transportation Users

Macrozone	Sample size	Income	Destination	Fuel type	Travel time	Transport cover	Most important expenses	Effect of transportation cost
Sul (Private)	4	W6: 100%	Praca_Maua: 75% Centro: 25%	Gasoline: 100% Alcohol: 50%	30 min: 75% 30 min - 1 hour: 25%	Total Cover: 25% Partial Cover: 25% No Cover: 50%	a: 75% C: 25%	a (3) b (2) c (2)
Barra-Recreio (Private)	4	W4: 25% W5: 50% W6: 25%	Sul: 25% Praca_Maua: 25% Centro: 50%	Gasoline: 100% Alcohol: 50%	30 min - 1 hour: 50% 1 hour - 1,5 hour: 50%	Total Cover: 50% No Cover: 50%	a: 75% C: 25%	c (3)
Central (Private)	8	W4: 50% W5: 38% W6: 13%	Sul: 13% Barra-Recreio: 13% Jacarepagua: 13% Praca_Maua: 63%	Gasoline: 75% Alcohol: 88% Natural Gas: 13%	30 min: 63% 30 min - 1 hour: 37%	Total Cover: 25% Partial Cover: 13% No Cover: 63%	a: 75% b: 25%	b (2) c (2)
Norte (Private)	14	W3: 14% W4: 14% W5: 36% W6: 36%	Sul: 7% Barra-Recreio: 14% Central: 14% Norte: 36% Oeste-Rio: 21% Praca_Maua: 7%	Gasoline: 93% Alcohol: 64% Natural Gas: 21% Diesel: 7%	30 min: 43% 30 min - 1 hour: 36% 1 hour - 1,5 hour: 21%	Total Cover: 22% Partial Cover: 14% No Cover: 64%	a: 93% C: 7%	b (2) c (2) Nothing (2)
Oeste-Rio (Private)	2	W3: 50% W4: 50%	Barra-Recreio: 50% Central: 50%	Gasoline: 100% Alcohol: 50% Natural Gas: 50%	30 min - 1 hour: 50% 1 hour - 1,5 hour: 50%	Partial Cover: 50% No Cover: 50%	a: 100%	b (2) c (2)
Jacarepagua (Private)	2	W3: 50% W6: 50%	Barra-Recreio: 50% Praca_Maua: 50%	Gasoline: 100% Alcohol: 100% Natural Gas: 50%	30 min - 1 hour: 50% 1 hour - 1,5 hour: 50%	Total Cover: 50% Partial Cover: 50%	a: 100%	a (4) b (4) c (4)
Tijuca (Private)	6	W3: 17% W4: 33% W5: 33% W6: 17%	Norte: 17% Praca_Maua: 67% Centro: 17%	Gasoline: 83% Alcohol: 50% Diesel: 17%	30 min: 33% 30 min - 1 hour: 67%	Total Cover: 33% No Cover: 67%	a: 67% C: 33%	b (3) c (2)
Praca_Maua (Private)	2	W4: 50% W5: 50%	Sul: 50% Tijuca: 50%	Gasoline: 100%	30 min: 50% 30 min - 1 hour: 50%	Total Cover: 50% No Cover: 50%	a: 50% b: 50%	a (4) b (4) c (2)
Centro (Private)	3	W2: 33% W3: 33% W5: 33%	Sul: 33% Praca_Maua: 67%	Gasoline: 100% Alcohol: 67%	30 min: 100%	Total Cover: 33% Partial Cover: 33% No Cover: 33%	a: 67% b: 33%	a (2) b (2) c (2)

Table 46: Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Private Transportation Users – Part 1

Macrozone	Why private?	50%	100%	No Fossil Fuels
Sul (Private)	**Private transportation is more comfortable (3); I like to go by private transportation (3);I'm already used to using private transport (3).**	**I would continue using the car (4)**	**I would continue using the car (4)**	**Would use alcohol as fuel (4)**
Barra-Recreio (Private)	**Because it has no subway in my neighborhood (3)**	**I would continue using the car (3)**	I would stop using the car (2)	I would stop using the car (2); I would move closer to the work (2); I would look for a job closer to home (2)
Central (Private)	**By bus it takes too long (3); Public transportation is uncomfortable (3).**	**I would continue using the car (3);This value affects my personal spending, but I would continue using private transport (3); Would use alcohol as fuel (3)**	Would use alcohol as fuel (2); I would use public transportation (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2)	**Would use alcohol as fuel (3)**
Norte (Private)	**Private transportation is more comfortable (3); I like to go by private transportation (3).**	I would continue using the car (2); This value affects my personal spending, but I would continue using private transport (2); Would use alcohol as fuel (2)	I would continue using the car (2); Would use alcohol as fuel (2)	**Would use alcohol as fuel (4)**
Oeste-Rio (Private)	**Private transportation is more comfortable (4); Despite it affect my personal expenses, I prefer to use private transportation (4); BRT is full (4).**	I would continue using the car (2); This value affects my personal spending, but I would continue using private transport (2); I Would do my activities closer to home (shopping, etc.) (2); I would use the natural gas (2); I believe that the government would subsidize the price of gasoline to maintain lowest price (2); I would use the bus or BRT (2).	I would continue using the car (2); I would use the bus or BRT (2); I would use the natural gas (2);I believe that the government would subsidize the price of gasoline to maintain lowest price (2)	**I would stop using the car (4)**
Jacarepagua (Private)	**Private transportation is more comfortable (4); By bus it takes too long (4); I like to go by private transportation (4); I feel safer in private transportation (4); Because it has no subway in my neighborhood (4).**	**I would continue using the car (4)**	I would continue using the car (2); I would use public transportation (2); I would use the bus or BRT (2); This does not affect my personal expenses, I would continue using private transport (2); I would use the natural gas (2)	**I would stop using the car (4)**
Tijuca (Private)	**By bus it takes too long (4); Public transportation is uncomfortable (4).**	**I would continue using the car (4); This value affects my personal spending, but I would continue using private transport (3)**	This value affects my personal spending, but I would continue using private transport (2); This does not affect my personal expenses, I would continue using private transport (2)	Would use alcohol as fuel (2); I would continue using the car (2)
Praca_Maua (Private)	**Private transportation is more comfortable (4); By bus it takes too long (4); Public transportation is uncomfortable (4); It's cheaper than public transport (4): Metro is full (4): Public transportation is expensive (4).**	This value affects my personal spending, but I would continue using private transport (2); I believe that the government would subsidize the price of gasoline to maintain lowest price (2); I would cycle to work (2); I would look for a job closer to home (2); I would use the motorcycle (2)	**I would use public transportation (4)**	I would move closer to the work (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I believe that the government would subsidize the price of gasoline to maintain lowest price (2); I would cycle to work (2); I would use the metro (2); I would walk (2); I would use the train (2)
Centro (Private)	**By bus it takes too long (4); Public transportation is uncomfortable (4); Private transportation is more comfortable (3); Because it has no subway in my neighborhood (3); Despite it affect my personal expenses, I prefer to use private transportation (3)**	**I would continue using the car (4); This value affects my personal spending, but I would continue using private transport (4)**	**I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (3)**	**Would use alcohol as fuel (3)**

Table 47: Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Private Transportation Users – Part 2

Macrozone	Job	Services	Bicycle	Why not cycle?
Sul (Private)	Very difficult: 25% Easy: 25% Do not know: 50%	Easy: 25% Very easy: 75%	Yes: 100%	No highlighted reason
Barra-Recreio (Private)	Difficult: 100%	Very easy: 100%	Yes: 25% No: 75%	**Distance (4); Climate (3);**
Central (Private)	Very difficult: 38% Difficult: 38% Easy: 13% Do not know: 11%	Difficult: 13% Easy: 75% Very easy: 13%	Yes: 75% No: 25%	**Lack of parking (4); Fear of being stolen (4)**
Norte (Private)	Very difficult: 21% Difficult: 36% Easy: 21% Very easy: 14% Do not know: 8%	Difficult: 21% Easy: 57% Very easy: 21%	Yes: 36% No: 64%	**Distance (4); Lack of parking (3)**
Oeste-Rio (Private)	Very difficult: 100%	Difficult: 50% Easy: 50%	No: 100%	Distance (2); Lack of parking (2); Fear of being stolen (2)
Jacarepagua (Private)	Very difficult: 50% Difficult: 50%	Easy: 50% Very easy: 50%	Yes: 50% No: 50%	**Distance (4); I do not know how to ride a bike (4)**
Tijuca (Private)	Very difficult: 67% Difficult: 17% Do not know: 16%	Easy: 33% Very easy: 67%	Yes: 67% No: 33%	Distance (2); Climate (2); I am not use to using the bicycle (2)
Praca_Maua (Private)	Difficult: 100%	Difficult: 50% Easy: 50%	Yes: 100%	No highlighted reason
Centro (Private)	Very difficult: 100%	Very difficult: 33% Difficult: 33% Very easy: 33%	No: 100%	**Lack of parking (3); Fear of being stolen (3)**

Table 46 and Table 47 are related to the adaptability stage in the macrozone Sul, and the highlighted variables that can affect the resilience of the respondents are the attitude towards "why they use private transportation?" and how they would react in each case scenario (H2, H3 and H4). First, most agreed that they are already going to use private transportation, reflecting the habit. On all proposed scenarios, majority in this macrozone agreed that they would continue using private transportation.

Furthermore, 25% of the respondents agree that it is easy to find a job in the same or in the neighbourhood district where they live, which is a low value. Whereas 100% agrees that, it is easy to find services (e.g. shopping, culture, markets, doctors, etc.). Although respondents maintain the use of private transportation in all scenarios, they mostly agree that it is possible to cycle to a nearby train or metro station.

In **macrozone Barra-Recreio**, for the persistence stage of analysis, the highlighted variables that show vulnerability towards a price increase in fossil fuels are fuel type, travel time and destination. Concerning the fuel type, it has the same characteristics as macrozone Sul. In relation to travel time, 50% takes more than one hour to reach the designated destination. Lastly, the destination variable shows that 25% of the respondents travel to a neighbourhood macrozone to reach work and no one works in the same macrozone where they reside.

With regard to the adaptability stage of analysis, the highlighted variables are the scenario of 50% increase of oil price, which the respondents would continue to use for private transportation, although they are already sacrificing their monthly savings. Overall, the respondents do not show a major reluctance towards public transportation, however, the attitude towards a crisis improves from the H3 (100%) scenario ahead, where there is a level of agreement that respondents would shift to public transportation, search for a job near their residence or move their residence nearer to their workplace. Besides, most agreed that it is not possible to cycle to a nearby train or metro station, mainly because of the distance and climate.

In **macrozone Central**, the highlighted variable related to the persistence stage of analysis that can affect persistence when faced with a fossil fuel threat is transport cover. Only 25% of the interviewees have total transport cover, while the other 75% has to cover the monthly transportation cost partially or totally. Some of the respondents affirm that they have already sacrificed their savings and partly sacrificed the costs of leisure and others.

The analysis of the adaptability stage in the macrozone Central shows that the unfavourable variable to adapt to during a fossil fuel crisis is the reason of using private transportation ("why private?"). It reflects the attitude towards the H2 ("50%"), H3 ("100%") and H4 ("no fossil fuels") scenarios and the impression of how difficult it is to find a job in the same or neighbourhood district ("job").

The reason of using private transportation shows negative responses towards public transportation, leading to a possible reluctance to use public transportation in a crisis scenario. In the 50% increase of oil price scenario, most responses tend towards the continuing the use of private transportation with a shift to alcohol as fuel, although respondents affirm that this would affect personal expenses.

The 100% increase of oil price scenario shows that the highlighted answers were related to the continuing of the use of private transportation, using alcohol as fuel. There is also a level of agreement that interviewees would avoid when doing other activities to spend less. However, a part would shift to public transportation. In the "no oil" scenario, the majority agreed that they would use alcohol as fuel, therefore maintaining the private transportation use.

Furthermore, most agreed that it is difficult to find a job in the same or neighbourhood district. On the other hand, it is possible to cycle to train or metro stations. However, some agree that lack of parking and fear of the bicycle being stolen may influence the use of bicycles.

In **macrozone Norte**, the variable that can affect persistence is transportation cover, which is 78%, and out of which there is partial (14%) or no cover (64%) on transportation cost. In the adaptability analysis, the highlighted variables are all attitude variables related to reasons why people would use private transportation in the possible threat scenarios. Furthermore, other variables influencing the adaptability are "how hard it is to find a job in the same or neighborhood district" and the possibility of using the bicycle to reach a train or metro station.

In this macrozone, most agreed that they like to use private transportation and it is more comfortable, although for some, it already affects savings and expenses with leisure and others. In the H2 scenario, the affirmations with higher agreement rate were those related to the continuity of using private transportation and that this would affect their personal expenses and a possible shift to alcohol as fuel. The H3 and H4 scenarios follow the same patterns from the H2 scenario. Furthermore, most agreed that it is difficult to find a job in the same or neighbourhood district and it is difficult to cycle to a train or metro station because of the distance and lack of parking facilities.

In **macrozone Oeste-Rio**, there are four variables in the persistence stage of analysis that can affect the reaction of respondents during a fossil fuel threat: income, fuel type, time and transport cover. The income variable shows that 50% of the respondents earn until two minimum salaries (W3). The fuel type variable is similar to the macrozones Sul and Barra-Recreio. In terms of time, half of the respondents take more than one hour to reach work. Regarding the transportation cover, 50% of the respondents have no cover of transportation cost from the contractor, while the other half has total cover. Besides these factors, part of the respondents already affirmed that they sacrifice leisure and other costs and savings, because of the recent increase in gasoline price.

The adaptability stage of analysis of this macrozone shows that six variables can affect the resilience of urban mobility: reason why to use private transportation, H2 scenario, H3 scenario, job variable, services variable and bicycle use. This macrozone shows high rate of agreement of the following affirmations: "private transportation is more comfortable"; despite it already affects my personal expenses, I prefer to use private transportation"; and "BRT is full".

Many respondents admitted that they already sacrifice personal expenses, such as with leisure and savings, but still prefer private transportation. This reflects a reluctance to shift to public transportation.

In the H2 and H3 scenarios, the majority of highlighted responses are related to the continuity of the use of private transportation. Only in the H4 scenario, respondents are willing to shift to public transportation. In relation to the job positions, 100% affirmed that it is difficult to find a job in the same or neighbourhood district where they reside. In relation to the services, 50% of respondents believe it is difficult to find services in the same and neighbourhood districts. The bicycle variable shows that 100% of respondents said that it is not possible to reach a train and metro station on a bicycle from their residence, because of the distance, lack of parking and fear of the bicycle being stolen.

In **macrozone Jacarepagua**, the persistence analysis shows that five variables can affect the resilience of urban mobility: income, destination, time, transport cover and effect on personal costs. In relation to the income, 50% earns until two minimum salaries (W3). The destination variable shows that 50% of the respondents work in neighbourhood macrozones and no respondents work in the same macrozone where they live and 50% of the respondents take more than one hour to reach work. Furthermore, 50% of respondents have no transportation cover from their contractors. Besides these factors, all respondents agree that they have already sacrificed basic needs, leisure costs and savings.

In the adaptability stage of analysis, five variables can affect the resilience level: the attitude towards private transportation, scenario H2, scenario H3, job variable and bicycle variable. The reason why the respondents use private transportation in this macrozone is that it is more comfortable, "by bus it takes too long", they like to use private transportation because they feel safer and there is no metro accessible.

The 50% fuel-price-increase scenario shows that most of the highlighted answer is that they would continue using private transportation, although they already feel like they have sacrificed their personal expenses. The 100% fuel-price-increase scenario shows that a part would shift to public transportation and the other part would continue using private transportation. In the H4 scenario, where there is no oil, majority would shift to public transportation.

Regarding the question of how difficult it is to find a job in the same or neighbourhood district from their residence, 100% affirmed it is difficult to find a job. In relation to the bicycle use, 50% affirmed it is not possible to reach a train or metro station by bicycle from their residence, because of the distance and lack of ability to ride a bicycle.

In **macrozone Tijuca**, the persistence analysis stage presents two variables that can influence the resilience of urban mobility: fuel type and transportation cover. In relation to the fuel type, 50% of interviewees use alcohol, 83% use gasoline and 17% diesel as fuel for private transportation. Regarding transportation cover, 63% has no cover for transportation cost from their contractors.

The adaptability stage of analysis shows that five variables can influence the resilience of urban mobility: the reason for using private transportation, the attitude towards the H2, H3, and H4 threat scenarios and the job variable.

Most affirmed that they use private transportation because it takes too long by bus and public transportation is uncomfortable. In the H2 scenarios, most agreed that although this increase would affect personal expenses, they would continue using private transportation. In the H3 scenario, the same pattern continues, as in H2 and in the H4 scenario, there is the continuity of the private transportation pattern, where some would shift the fuel use to alcohol. In relation to the how difficult it is to find a job in the same or neighbourhood district from residence, most agreed that it is difficult to find a job in this area.

In **macrozone Praca_Maua**, four variables affect the persistence stage of resilience: destination, fuel type, transport cover and effect of transportation cost on basic needs. In relation to the destination, 50% of the interviewees who work at a neighbourhood macrozone and no one work at the same macrozone in which they live. Regarding the fuel type, 100% uses gasoline as fuel. Furthermore, 50% of the respondents have no transportation cover costs from their contractors. Besides this, most agree that they have already sacrificed expenses on basic needs and leisure, because of the recent increase in fuel price.

The reason why using public transportation, plus the job and services variables can be influential on the resilience of urban mobility in this macrozone is that using private transportation is related to dissatisfaction with public transportation, such as long time to reach work through public transportation, lack of comfort of public transportation and expensive price of public transportation. Although the reasons to use private transportation are related to a negative view of public transportation, in the threat scenarios, the respondents presented flexible attitude towards shifting to public transportation, to cycle, to work and even to search for a job near home. Regarding the job variable, 100% think it is difficult to find a job in the same or neighbourhood district. In relation to services, this number is 50%.

In **macrozone Centro**, three variables affect the resilience of urban mobility: income, transport cover and effect of transportation cost on basic needs. In relation to the income, 66% of respondents have income until two minimum salaries (W3). Regarding transportation cover, 66%

of interviewees has partial or no cover from their contractors, while 33% has total cover. Furthermore, the respondents already feel that they have sacrifices personal expenses with part sacrifice costs on basic needs, part sacrifice costs with leisure and part sacrificing their savings.

In the adaptability stage, all of the variables can be highlighted as influencing the resilience of urban mobility. In relation to the reason why respondents are using private transportation, most highlighted affirmations are: “by bus it takes too long”; “public transportation is uncomfortable”; “private transportation is more comfortable”; “because there is no metro in my district”; despite the fact that it is already affecting the personal expenses of respondents, they prefer private transportation.

In all threat scenarios, the interviewees tend to continue using private transportation, although it already affects personal expenses. In the H2 threat scenario, they even agree that they would avoid doing other activities to save for the transportation costs. In the H4 scenario, most would shift to alcohol for fuel.

In relation to the job variable, 100% agree that it is difficult to find a job in the same or neighbourhood district. Regarding the services, 66% find it difficult to find services in the same or neighbourhood district and 100% of respondents believe that it is difficult to reach a train or metro station by bicycle, because of lack of parking and fear of it being stolen.

8.3.2.2. Public Transportation User’s Analysis

This section is an analysis of the approximately 68.5% of the sample that can be characterised as the group of people who use public transportation and may have strong tendency in persisting public transportation use during a fossil fuel threat.

In **macrozone Sul**, three variables that can affect the persistence stage in the resilience of urban mobility: transportation mode, transport cover and effect of transportation cost on basic needs. In relation to transportation mode, 77% of respondents use bus and 42% metro. This shows that to reach work, most use bus or combines bus and metro, which is a more expensive combination.

Table 48: Variables of the Persistence Stage of Analysis of the Qualitative Approach – Public Transportation Users

Macrozone	Sample size	Income	Destination	Transport Mode	Travel time	Transport cover	Most important expenses	Effect of transportation cost
Sul (Public)	43	W3: 28%; W4: 42%; W5: 14%; W6: 16%	Sul: 23%; Barra-Recreio: 2%; Oeste-Rio: 2%; Jacarepagua: 2%; Praca_Maua: 26%; Centro: 44%	Bus: 77%; BRT 5%; Metro: 42%; Train: 2%; Taxi: 5%; On foot: 16%; Bicycle: 7%	30 min: 30%; 30 min - 1 hour: 49%; 1 hour - 1.5 hour: 16%; 1.5 hour - 2 hours: 5%	Total Cover: 44% Partial Cover: 19% No Cover: 37%	a: 56% b: 21% C: 23%	a(2) b (2) c (2)
Barra-Recreio (Public)	3	W3: 33%; W4: 33%; W5: 33%	Sul:33%; Norte: 33%; Centro: 33%	Bus: 100%; BRT: 67%; On foot: 33%.	30 min - 1 hour: 33%; 1 hour - 1.5 hour: 33%; 1.5 hour - 2 hours: 33%	Total Cover: 67%; No Cover: 33%	a: 33% b: 33% C: 33%	**a(3)** **b (3)** **c (3)**
Central (Public)	31	W2: 3%; W3: 29%; W4: 58%; W5: 10%	Sul: 10%; Barra-Recreio: 10%; Norte: 16%; Tijuca: 6%; Praca_Maua: 13%; Centro: 45%	Bus: 81%; BRT: 16%; Metro: 26%; Train: 29%; Taxi: 6%; On foot: 13%	30 min: 6%; 30 min - 1 hour: 42%; 1 hour - 1.5 hour: 39%; 1.5 hour - 2 hours: 10%; 2 hours - 2.5 hours: 9%	Total Cover: 68%; Partial Cover: 3%; No Cover: 29%%	a: 68% b: 10% C: 23%	a(2) b (2) c (2)
Norte (Public)	54	W2: 6%; W3: 30%%; W4: 57%; W5: 7%	Sul: 17%; Barra-Recreio: 2%; Central 9%; Norte: 11%; Jacarepagua: 4%; Tijuca: 7%; Praca_Maua: 17%; Centro: 33%	Bus: 85%; BRT: 20%; Metro: 35%; Train: 19%; Van: 6%; Taxi: 4%; On foot: 13%; Bicycle: 6%; Ferrie: 4%	30 min: 7%; 30 min - 1 hour: 11%; 1 hour - 1.5 hour: 41%; 1.5 hour - 2 hours: 31%; 2 hours - 2.5 hours: 9%	Total Cover: 54%; Partial Cover: 15%; No Cover: 31%	a: 74% b: 7% C: 19%	a(2) b (2) c (2)
Oeste-Rio (Public)	21	W2: 5%; W3: 29%%; W4: 62%; W5: 5%	Sul: 5%; Barra-Recreio: 10%; Central: 10%; Norte: 14%; Jacarepagua: 5%; Praca_Maua: 10%; Centro: 48%	Bus: 81%; BRT: 29%; Metro: 24%; Train: 62%; Van: 14%; On foot: 29%	30 min - 1 hour: 5%; 1 hour - 1.5 hour: 14%; 1.5 hour - 2 hours: 43%; 2 hours - 2.5 hours: 24%; over 2.5 hours: 14%	Total Cover: 57%; Partial Cover: 19%; No Cover: 24%	a: 67% C: 33%	a(2) **b (3)** c (2)
Jacarepagua (Public)	19	W2: 5%; W3: 47%%; W4: 42%; W6: 5%	Sul: 21%; Barra-Recreio: 21%; Tijuca: 11%; Praca_Maua: 11%; Centro: 37%	Bus: 95%; BRT: 63%; Metro: 37%; Train: 16%; Taxi: 11%; On foot: 21%	30 min - 1 hour: 5%; 1 hour - 1.5 hour: 37%; 1.5 hour - 2 hours: 42%; 2 hours - 2.5 hours: 16%	Total Cover: 63%; Partial Cover: 21%; No Cover: 16%	a: 42% b: 11% C: 47%	**a(3)** **b (3)** **c (3)**
Tijuca (Public)	38	W2: 8%; W3: 39%%; W4: 45%; W5: 5%; W6: 3%	Sul: 18%; Barra-Recreio: 5%; Central: 3%; Jacarepagua: 3%; Tijuca: 3%; Praca_Maua: 11%; Centro: 58%	Bus: 74%; BRT: 3%; Metro: 50%; Train: 3%; Taxi: 8%; On foot: 13%; Bicycle: 5%	Until 30 min: 34% ; 30 min - 1 hour: 32%; 1 hour - 1.5 hour: 21%; 1.5 hour - 2 hours: 8%; 2 hours - 2.5 hours: 3%; over 2.5 hours: 3%	Total Cover: 61%; Partial Cover: 8%; No Cover: 32%	a: 79% b: 8% C: 13%	b (2) c (2)
Praca_Maua (Public)	29	W2: 7%; W3: 41%%; W4: 52%;	Sul: 14%; Barra-Recreio: 10%; Central: 3%; Norte: 7%; Tijuca: 7%; Praca_Maua: 10%; Centro: 48%	Bus: 93%; BRT: 24%; Metro: 48%; Train: 17%; Van: 10%; On foot: 14%	Until 30 min: 3% ; 30 min - 1 hour: 31%; 1 hour - 1.5 hour: 48%; 1.5 hour - 2 hours: 14%; 2 hours - 2.5 hours: 3%	Total Cover: 41%; Partial Cover: 14%; No Cover: 45%	a: 69% b: 3% C: 28%	**a(3)** **b (3)** **c (3)**
Centro (Public)	15	W3: 40%%; W4: 53%; W5: 7%	Sul: 20%; Barra-Recreio: 7%; Tijuca: 7%; Praca_Maua: 13%; Centro: 53%	Bus: 80%; Metro: 40%; Taxi: 13%; Van: 10%; On foot: 27%; Bicycle: 13%	Until 30 min: 40% ; 30 min - 1 hour: 40%; 1.5 hour - 2 hours: 20%	Total Cover: 53%; Partial Cover: 20%; No Cover: 27%	a: 53% b: 20% C: 27%	a(2) b (2) c (2)

Table 49: Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Public Transportation Users – Part 1

Macrozone	Why public?	50%	100%	No Fossil Fuels
Sul (Public)	**It's cheaper than private transport (3)**	The company that hires me would support me (2); This value would affect my personal expenses, but I would continue using the bus (2); I would continue using the bus / van / BRT (2)	This value would affect my personal expenses, but I would continue using the bus (2); The company that hires me would support me (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I would continue using the bus / van / BRT (2); I would cycle to work (2)	I would use the train or metro (2); I would cycle to work (2); I believe that the Government would act and present an alternative solution (2)
Barra-Recreio (Public)	**I can do other things on the way (study, read, reply e-mails, etc.) (4); I have a car, but I prefer to use public transport (3)**	This value would affect my personal expenses, but I would continue using the bus (2); I do not use the bus / BRT / Van, then I would continue using the metro or train (2); I would move closer to the work (2)	I do not use the bus / BRT / Van, then I would continue using the metro or train (2); I would move closer to the work (2); I would use private transport (2)	I would use the train or metro (2); I would use private transport (2); I would move closer to the work (2)
Central (Public)	**I am not satisfied with public transport, but it is the only option for me (3); Because I have no money for a private transportation (3)**	**This value would affect my personal expenses, but I would continue using the bus (3)**	This value would affect my personal expenses, but I would continue using the bus (2); The company that hires me would support me (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I would continue using the bus / van / BRT (2); I would use the train or metro (2)	**I would use the train or metro (3)**
Norte (Public)	**Because I have no money for a private transportation (3)**	The company that hires me would support me (2); This value would affect my personal expenses, but I would continue using the bus (2); I would continue using the bus / van / BRT (2)	This value would affect my personal expenses, but I would continue using the bus (2); The company that hires me would support me (2); I would continue using the bus / van / BRT (2);	I would use the train or metro (2)
Oeste-Rio (Public)	**I am not satisfied with public transport, but it is the only option for me (4); Because I have no money for a private transportation (3); I do not feel safe, but it is the only option for me now (3)**	**The company that hires me would support me (3); I would continue using the bus / van / BRT (3)**	**I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (3)**	I would use the train or metro (2); I believe that the Government would act and present an alternative solution (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); The company hires me would act and present an alternative solution (2)
Jacarepagua (Public)	**I am not satisfied with public transport, but it is the only option for me (3); Because I have no money for a private transportation (3); I do not feel safe, but it is the only option for me now (3)**	The company that hires me would support me (2); This value would affect my personal expenses, but I would continue using the bus (2); I would continue using the bus / van / BRT (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2)	This value would affect my personal expenses, but I would continue using the bus (2); The company that hires me would support me (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I would continue using the bus / van / BRT (2)	I believe that the Government would act and present an alternative solution (2); I would use private transport (2)
Tijuca (Public)	**I am not satisfied with public transport, but it is the only option for me (3)**	The company that hires me would support me (2); This value would affect my personal expenses, but I would continue using the bus (2); I would continue using the bus / van / BRT (2);I would use the train or metro (2)	This value would affect my personal expenses, but I would continue using the bus (2); The company that hires me would support me (2).	**I would use the train or metro (3)**
Praca_Maua (Public)	**I am not satisfied with public transport, but it is the only option for me (4); Because I have no money for a private transportation (3)**	**The company that hires me would support me (3); This value would affect my personal expenses, but I would continue using the bus (3)**	**This value would affect my personal expenses, but I would continue using the bus (3)**	**I would use the train or metro (3)**
Centro (Public)	**It's cheaper than private transport (3)**	This value would affect my personal expenses, but I would continue using the bus (2); I would continue using the bus / van / BRT (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I would use the train or metro (2); I would cycle to work (2); I would walk (2)	This value would affect my personal expenses, but I would continue using the bus (2); The company that hires me would support me (2); I would continue using the bus / van / BRT (2); I would cycle to work (2); I would stop going by bus, BRT or van (2) ; I would walk (2)	**I would cycle to work (3)**

Table 50: : Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Public Transportation Users – Part 2

Macrozone	Job	Services	Bicycle	Why not cycle?
Sul (Public)	Very difficult: 30% ; Difficult: 40%; Easy: 16% Very Easy: 2%; Do not know: 12%	Difficult: 2% ; Easy: 26% Very Easy: 72% ;	Yes: 84% No: 16%	No highlighted reason
Barra-Recreio (Public)	Very difficult: 33% ; Difficult: 33%; Do not know: 34%	Easy: 33% Very Easy: 67% ;	No: 100%	**Distance (3)**
Central (Public)	Very difficult: 58% ; Difficult: 35%; Easy: 3% Very Easy: 3%;	Very difficult: 10% ; Difficult: 26% ; Easy: 35% Very Easy: 29%;	Yes: 55% No: 45%	Lack of parking (2)
Norte (Public)	Very difficult: 44% ; Difficult: 43%; Easy: 4% Very Easy: 4%; Do not know: 5%	Very difficult: 6% ; Difficult: 22%; Easy: 46%; Very Easy: 26%;	Yes: 43% No: 57%	Distance (2); Lack of parking (2); Fear of being stolen (2)
Oeste-Rio (Public)	Very difficult: 38% ; Difficult: 43%; Easy: 5% Do not know: 14%	Very difficult: 5% ; Difficult: 29% ; Easy: 48% Very Easy: 19%;	Yes: 76% No: 24%	No highlighted reason
Jacarepagua (Public)	Very difficult: 42% ; Difficult: 47%; Very Easy: 5%; Do not know: 6%	Very difficult: 5% ; Difficult: 11% ; Easy: 68% Very Easy: 16% ;	Yes: 16% No: 84%	**Distance (4)**
Tijuca (Public)	Very difficult: 34% ; Difficult: 45%; Easy: 5% Do not know: 16%	Very difficult: 3% ; Difficult: 8%; Easy: 39% Very Easy: 50% ;	Yes: 87% No: 13%	No highlighted reason
Praca_Maua (Public)	Very difficult: 48% ; Difficult: 41%; Easy: 3% Do not know: 8%	Very difficult: 3% ; Difficult: 45%; Easy: 41% Very Easy: 10% ;	Yes: 55% No: 45%	Lack of parking (2); Fear of being stolen (2)
Centro (Public)	Very difficult: 13% ; Difficult: 33%; Easy: 33% Very Easy: 7%; Do not know: 14%	Very difficult: 13% ; Difficult: 7%; Easy: 47% Very Easy: 33%;	Yes: 87% No: 13%	No highlighted reason

In the adaptability analysis of the macrozone Sul, three variables can influence the resilience of urban mobility: H2 threat scenario, H3 threat scenario and job variable. Regarding the attitude of the respondents in the H2 threat scenario, the highlighted affirmations are that "the company that hires me would support me"; the increase would affect personal expenses and they would continue to use buses, vans or BRT. In relation to the job variable, 70% of the respondents believe that it is difficult to find a job in the same or neighbourhood district.

In **macrozone Barra-Recreio**, in the persistence stage of analysis, four variables can affect the resilience of urban mobility: destination, transportation mode, time and effect of transportation costs on basic needs. In relation to the destination variable, 33% of the interviewees work in a neighbourhood macrozone. No interviewee works in the same macrozone where they live. The number of respondents who use bus is 100%, while no one uses metro or train. Regarding travel time, 66% of the interviewees take more than one hour to reach work. Most of the respondents affirm that they already sacrifice costs with basic needs, leisure expenses and savings.

Four variables can affect the resilience in the adaptability stage in macrozone Barra-Recreio: attitude in the H2 scenario, H3 threat scenarios, job variable and bicycle variable. In relation to the attitude in the H2 threat scenario, the highlighted affirmations are that the increase would affect personal expenses, some would use metro and some would move closer to work. Faced with the H3 threat scenario, some would use metro, some would move closer to work; some would shift to private transportation. In relation to the job variable, 66% agreed that it is difficult to find a job in the same and neighbourhood district. Furthermore, 100% agree that it is not possible to reach a train or metro station by bicycle, because of distance.

In **macrozone Central**, the persistence analysis shows four variables that can affect the resilience of urban mobility: destination, transportation mode, time and effect of transportation cost on basic needs. In relation to the destination variable, 35% of interviewees work in a neighbourhood macrozone, while no one works in the same macrozone that they live in. In relation to the transportation mode, most of respondents use bus (81%), and 26% uses metro and 29% train. These values show that there is a large part of interviewees who use only bus and some that mix bus with metro or train, but these combinations make transportation cost higher.

Regarding the time spent in transportation, 52% takes more than one hour to reach work. In relation to the effect of transportation cost on personal expenses, some interviewees (25%–50%) affirm that they already make sacrifices on expenses related to basic needs; some also sacrifice leisure expenses and savings.

The adaptability analysis of this macrozone shows that four variables can affect the resilience of urban mobility: why they use public transportation, H2 threat scenario, H3 threat scenario and job variable. In this macrozone, most interviewees believe that public transportation is the only option, although they dislike it. Furthermore, respondents do not use private transportation, because they have no money for it (under their perspective).

In the H2 threat scenario, most agreed that this value would affect their personal expenses, but they would continue accessing the bus. In the H3 threat scenario, some agreed that this would affect their personal expense, however they would continue using the bus; some believe that their contractors would support them in this situation, some would avoid doing other activities and some would shift to metro or train. The job variable shows that 94% of respondents believe it is difficult to find a job in the same or neighbourhood district.

In **macrozone Norte**, four variables can influence the persistence stage of the resilience analysis: destination, transportation mode, time and effect of transportation cost on basic needs. In relation to the destination, 37% of interviewees work in the same or neighbourhood macrozones. Regarding the transportation mode, 85% of respondents use bus, while 35% uses metro and 19% train. The time variable shows that 82% of interviewees take more than one hour to reach work. Furthermore, some already sacrifice expenses with basic needs, leisure and monthly savings.

Five variables can influence the adaptability stage of the resilience analysis: the reason why they use public transportation; the attitude during the H2 threat scenario, H3 threat scenario, job variable and bicycle variable. In relation to the reason why they use public transportation, most agreed that it is because they have no money for private transportation. In the H2 threat scenario, the highlighted affirmation is that some respondents believe that the contractors would support them; some believe that this value would affect personal expenses; however, they would continue to use the bus. The H3 scenario threat follows the same pattern as the H2 scenario. Regarding the job variable, 87% of interviewees believe it is difficult to find a job in the same or neighbourhood district. Furthermore, 57% affirms that it is not possible to reach a train or metro station by bicycle, because of distance, lack of parking and fear of it being stolen.

In **macrozone Oeste-Rio**, four variables can influence the resilience of urban mobility: destination, transportation mode, time and effect of transportation cost on basic needs. In relation to destination, 39% of the respondents work in neighbourhood macrozones, no one works in the same macrozone where they live. Regarding transportation mode, 81% uses bus, 61% trains, 29% BRT and 24% metro. These values indicate that respondents combine bus and metro or train, leading to higher transportation costs. The time variable shows that 95% of respondents take more than one hour to reach work. Most of the respondents already sacrifice leisure expenses, some sacrifice basic needs and monthly savings.

In the adaptability stage of analysis, four variables influence resilience: the reason why using public transportation, attitude during the H2 threat scenario, H3 threat scenarios and job variable. In relation to the reasons of using public transportation, most of the respondents affirmed that they are not satisfied with public transportation and they do not feel safe, but it is the only option. In addition, they have no money to use private transportation.

Regarding the H2 threat scenario, most affirmed that the contractor would support them and they would continue to use buses, vans or BRT. In the H3 scenario, most affirmed that they would avoid doing other activities, maintaining their mobility pattern. In relation to the job variable, 82% believe it is difficult to find a job in the same or neighbourhood district.

In **macrozone Jacarepagua**, four variables can influence the resilience of urban mobility: income, transportation mode, time and the effect of transportation cost on basic needs. In relation to income, 53% of respondents earn less than two minimum salaries (W3). The transportation mode variable shows that 95% of the respondents use bus, 63% BRT, 37% metro and 16% train. These values show the mixed use of transportation modes to reach work.

The time variable shows that 95% of the respondents spends more than one hour to reach work. Furthermore, most of the interviewees already sacrifice expenses with basic needs, leisure and monthly savings.

In the adaptability stage of evaluation, six variables affect the resilience of urban mobility: all attitude variables, job variable and bicycle variable. The reasons why respondents use public transportation are related to the lack of option, because they have no money for private transportation, although respondents do not feel safe in public transportation.

In relation to the attitude when faced with the H2 threat scenario, the highlighted affirmations are that “the company that hires me would support me”; “these values would affect my personal expenses, but I would continue using the bus”; “I would continue to use bus, van or BRT” and “I would avoid doing other activities”. In the H3 threat scenario, the highlighted affirmations are the same as H2. In the H4 threat scenario, there is a belief that the government would act and propose a solution and some respondents would shift to private transportation.

In relation to the job variable, 89% of respondents affirm that it is difficult to find a job in the same or neighbourhood district. Regarding the bicycle use, 84% of respondents affirm that it is not possible to reach a train or metro station by bicycle, mainly because of distance.

In **macrozone Tijuca**, two variables in the persistence analysis can influence the resilience of urban mobility: transportation mode and effect of transportation costs on personal expenses. The transportation mode variable shows that 74% of the respondents use bus and 50% use metro, leading to a mixed use of the transportation modes. Regarding the effects of transportation cost, some sacrifice leisure and other expenses and some sacrifice their monthly savings.

In the adaptability stage of analysis, four variables influence the resilience: reason why they use public transportation, H2 and H3 threat scenarios and job variable. The variable related to the reason why they use public transportation shows that the highlighted affirmation is that respondents are not satisfied with public transportation but it is the only option.

Regarding the H2 threat scenarios, the highlighted affirmations are that some believe that the contractor would act to support them; some affirm that this value would affect personal expenses; however, they would continue to use buses, vans or BRT. Some would shift to metro or train. The H3 follows the similar pattern as H2. In relation to the job variable, 79% of the respondents believe that it is difficult to find a job in the same or neighbourhood district.

In **macrozone Praca_Maua**, four variables influence the persistence stage of resilience: transportation mode, time, transportation cover and effect of transportation cost on personal expenses. The transportation mode variable, 93% of the respondents use bus, 48% metro, 24% BRT and 17% train, leading to a mixed use of public transportation. Regarding the time variable, 66% of the interviewees take more than one hour to reach work. The transportation cover's data show that 59% of the respondents have to deal totally (45%) or partially (14%) with the transportation costs. The data of transportation cost effects on personal expenses show that part of the respondents already sacrifice expenses with basic needs, leisure and monthly savings.

The adaptability stage of analysis has four variables that can influence the resilience of urban mobility: the reason why using public transportation, the attitude faced during the H2 and H3 threat scenarios and job variable. In relation to the reason of using public transportation, the highlighted affirmations are that the respondents are not satisfied with the system and that they have no money to pay for private transportation, therefore public transportation is the only option.

The H2 threat scenario shows that most interviewees agree that the contractor would support them and that the increase value of oil-based public transportation would affect personal expenses, however they would continue to use the bus. The H3 threat scenario has a similar pattern from the H2 threat scenario. Regarding the job variable, 89% of respondents believe that it is difficult to find a job in the same or neighbourhood district.

In **macrozone Centro**, there are two variables affecting the resilience of urban mobility in the persistence stage of analysis: transportation mode and effect of transportation cost on personal expenses. In relation to the transportation mode variable, 80% uses bus and 40% metro. Regarding the transportation cost effect on personal expenses, some respondents already sacrifice expenses with basic needs, leisure and monthly savings.

In the adaptability stage of analysis, one variable can affect the resilience of urban mobility: job variable. In relation to the job variable, 46% of the respondents believe that it is difficult to find a job in the same or neighbourhood district, 40% believes it is possible and 14% does not know.

8.3.2.3. Both transportation Users Analysis

This section is an analysis of approximately 19.2% of the sample, which can be characterised as the group of people who use public and private transportation, and may have a more flexible attitude towards threat scenarios.

In **macrozone Sul**, three variables influence the persistence stage of the resilience of urban mobility: transportation mode, transportation cover and effect of private transportation costs on personal expenses. The transport mode variable shows that 73% of the respondents use bus and 67% metro. Regarding transportation cover, 53% has to deal totally (33%) or partially (20%) with transportation costs. In relation to the effect of private transportation costs on personal expenses, the majority have already sacrificed monthly savings and some sacrifice expenses with basic needs.

In the adaptability stage of analysis, six variables influence the resilience of urban mobility: attitude when faced with H2, H3 and H4 threat scenarios of private transportation, attitude when faced with H3 and H4 threat scenarios of public transportation and job variable.

In relation to the private transportation threat scenarios, in the H2 scenario, some affirm that this would affect personal expenses, however they would continue to use private transportation; and some would shift to alcohol as fuel. In the H3 scenario, some would continue to use private transportation and some would use the bicycle. In the H4 scenario, some would continue using private transportation, shifting to alcohol as fuel and some would stop using private transportation.

In relation to the public transportation threat, scenarios, in the H3 scenario, although some would cycle to work, some believe that their contractor would support them in this scenario and some would shift to private transportation. In the H4 scenario, although some would use train, metro or bicycle, some would shift to private transportation. In relation to the job variable, 66% of the respondents believe it is difficult to find a job in the same or neighbourhood district from where they live.

Table 51: Variables of the Persistence Stage of Analysis of the Qualitative Approach – Both Transportation Users

Macrozone	Sample size	Income	Destination	Fuel type	Transport Mode	Travel time	Transport cover	Most important expenses	Effect of transportation cost (private)	Effect of transportation cost (public)
Sul (Both)	15	W3: 13%; W4: 47%; W5: 7%; W6: 33%	Sul: 27%; Barra-Recreio: 7%; Centro: 67%	Gasoline: 93% ; Etanol: 67%; Natural Gas: 13%;	Bus: 73%; Metro: 67%; Taxi: 13%; on foot: 7%; Bicycle: 7%;	30 min: 47%; 30 min - 1 hour: 40%; 1 hour - 1.5 hour: 13%;	Total Cover: 47%; Partial Cover: 20%; No Cover: 33%	a: 47% b: 33% C: 20%	a (2) **c (3)**	c(2); Nothing (2)
Barra-Recreio (Both)	10	W3: 20%; W4: 20%; W5: 30%; W6: 30%	Sul: 20%; Barra-Recreio: 20%; Praca_Maua: 40%; Centro: 20%	Gasoline: 100% ; Etanol: 60%;	Bus: 70%; BRT : 30%; Metro: 20%; Taxi: 20%;	30 min - 1 hour: 50%; 1 hour - 1.5 hour: 30%; 1.5 hour - 2 hours: 20%	Total Cover: 60%; Partial Cover: 20%; No Cover: 20%	a: 80%; C: 20%	b (2) c (2)	Nothing(2)
Central (Both)	9	W3: 22%; W4: 67%; W5: 11%	Sul: 33%; Praca_Maua: 22%; Centro: 44%	Gasoline: 67% ; Etanol: 56%;	Bus: 78%; BRT : 22%; Metro: 44%; Train: 44%; Van: 11%; Taxi: 22%; on foot: 22%;	30 min: 22%; 30 min - 1 hour: 11%; 1 hour - 1.5 hour: 33%; 1.5 hour - 2 hours: 22% ; 2 hours - 2.5 hours: 11%	Total Cover: 44%; Partial Cover: 22%; No Cover: 33%	a: 56% C: 44%	a (2) b(2) **c (3)**	**a(3)** b(2) **c(3)**
Norte (Both)	9	W3: 50%; W4: 25%; W5: 25%	Sul: 11%; Barra-Recreio: 11%; Norte: 22%; Oeste-Rio: 22%; Tijuca: 22%; Centro: 11%	Gasoline: 56% ; Etanol: 44%; Natural Gas: 11%	Bus: 89%; BRT: 33%; Metro: 33%; Van: 11%; on foot: 22%;	30 min: 11%; 30 min - 1 hour: 33%; 1 hour - 1.5 hour: 33%; 1.5 hour - 2 hours: 22%;	Total Cover: 44%; Partial Cover: 11%; No Cover: 44%	a: 78%; C: 22%	a(2) **b(3)** c(2)	**a(3)** b(2) c(2)
Oeste-Rio (Both)	9	W4: 67%; W5: 22%; W6: 11%	Sul: 11%; Barra-Recreio: 11%; Norte: 11%; Tijuca: 11%; Praca_Maua: 44%; Centro: 11%	Gasoline: 56% ; Etanol: 22%; Natural Gas: 11%;	Bus: 89%; BRT: 67%; Metro: 11%; Train: 33%; Taxi: 11%;	1 hour - 1.5 hour: 44%; 1.5 hour - 2 hours: 22%; 2 hours - 2.5 hours: 11%; Over 2.5 hours: 11%	Total Cover: 33%; Partial Cover: 11%; No Cover: 56%	a: 67% C: 33%	b(2) c(2)	a(2) **b(3)** **c(3)**
Jacarepagua (Both)	8	W3: 50%; W4: 25%; W5: 25%	Sul: 13%; Barra-Recreio: 38%; Jacarepagua: 13%; Centro: 38%	Gasoline: 75% ; Etanol: 63%;	Bus: 100%; BRT: 25%; Metro: 25%; Bicycle: 13%;	30 min: 25%; 30 min - 1 hour: 25%; 1 hour - 1.5 hour: 25%; 1.5 hour - 2 hours: 13% ; 2 hours - 2.5 hours: 13%	Total Cover: 50%; Partial Cover: 25%; No Cover: 25%	a: 63% b: 38%	b(2)	Nothing (2)
Tijuca (Both)	6	W2: 33%; W4: 33%; W5: 17%; W6: 17%	Sul: 17%; Praca_Maua: 33%; Centro: 50%	Gasoline: 67% ; Etanol: 50%;	Bus: 83%; Metro: 50%; on foot: 17%;	30 min: 17%; 30 min - 1 hour: 50%; 1 hour - 1.5 hour: 33%;	Total Cover: 50%; Partial Cover: 17%; No Cover: 33%	a: 67% b: 17% C: 17%	c(2)	b(2) c(2) Nothing (2)
Praca_Maua (Both)	4	W3: 50%; W4: 50%	Sul: 25%; Central: 25%; Centro: 50%	Gasoline: 50% ; Etanol: 25%; Natural Gas: 25%;	Bus: 100%; BRT: 25%; Metro: 25%; Train: 25%; Taxi: 25%;	30 min: 25%; 30 min - 1 hour: 25%; 1 hour - 1.5 hour: 25%; 1.5 hour - 2 hours: 25%;	Total Cover: 25%; Partial Cover: 50%; No Cover: 25%	a: 75% C: 25%	b(2) c(2)	a(2) **b(3)** **c(3)**
Centro (Both)	1	W5: 100%	Barra-Recreio: 100%	Gasoline: 100% ; Etanol: 100%;	Bus: 100%	2 hours - 2.5 hours: 100%	No Cover: 100%	a: 100%	**b(4)**	**b(4)**

Table 52: Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Both Transportation Users – Part 1

Macrozone	Why private?	50%	100%	No Fossil Fuels
Sul (Both)	**I like to go by private transportation (3); Private transportation is more comfortable (3)**	This value would affect my personal spending, but I would continue using private transport (2); I would use alcohol as fuel (2); I would continue using the car (2)	I would cycle to work (2); I would stop using the car (2); I would continue using the car (2)	I would use alcohol as fuel (2); I would stop using the car (2); I continue using the car (2)
Barra-Recreio (Both)	**Because it has no metro in my neighborhood (3); By bus it takes too long (3)**	I would use public transportation (2); I would use alcohol as fuel (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2)	I would stop using the car (2); I would use alcohol as fuel (2)	**I would use alcohol as fuel (3)**
Central (Both)	**Private transportation is more comfortable (4); By bus it takes too long (4); I like to go by private transportation (3)**	I would do my activities closer to home (shopping, etc.) (2); This value would affect my personal spending, but I would continue using private transport (2); I would use alcohol as fuel (2)	I would use public transportation (2); I would stop using the car (2)	I would use alcohol as fuel (2)
Norte (Both)	**I feel safer in private transportation (3)**	I would use public transportation (2); This value would affect my personal spending, but I would continue using private transport (2).	I would use public transportation (3)	I would use alcohol as fuel (2); I would stop using the car (2); I would cycle (2)
Oeste-Rio (Both)	**Public transportation is uncomfortable (4); Because it has no metro in my neighborhood (3); BRT is full (3); By bus it takes too long (3)**	**I would use public transportation (3)**	I would use the bus or BRT (2); I would stop using the car (2)	I would stop using the car (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I would use the metro or train (2)
Jacarepagua (Both)	**Public transportation is uncomfortable (4); Because it has no metro in my neighborhood (3); BRT is full (3); By bus it takes too long (3)**	This value would affect my personal spending, but I would continue using private transport (2); I would look for a job closer to home (2)	I would stop using the car (3)	I would use alcohol as fuel (2); I would do my activities closer to home (shopping, etc.) (2)
Tijuca (Both)	**By bus it takes too long (4)**	I would use public transportation (2); I would do my activities closer to home (shopping, etc.)(2); I would walk (2); I would use alcohol as fuel (2)	I would use public transportation (2); I would walk (2)	I would use alcohol as fuel (2); I would do my activities closer to home (shopping, etc.) (2); I would walk (2)
Praca_Maua (Both)	**Private transportation is more comfortable (3)**	I would use public transportation (2); I would use natural gas as fuel (2); I would use the metro (2); I would use the train (2)	I would use public transportation (2); I would cycle to work(2); I would use the bus or BRT (2); I would use the train (2); I would use the metro (2); I would go by van (2)	I would cycle (2); I would walk (2)
Centro (Both)	**Despite it affect my personal expenses, I prefer to use private transportation (4)**	**This value would affect my personal spending, but I would continue using private transport (4)**	**I would stop using the car (4)**	**I would use alcohol as fuel (4)**

Table 53: Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Both Transportation Users – Part 2

Macrozone	Why public?	50%	100%	No Fossil Fuels
Sul (Both)	It's cheaper than private transport (2); I can do other things on the way (study, read, reply e-mails, etc.) (2)	I would use the train or metro (2); The company that hires me would support me (2)	I would cycle to work (2); The company that hires me would bear the increase (2); I would use private transport (2)	I would go by train or metro (2); I would cycle (2); I would use private transport (2)
Barra-Recreio (Both)	**I can do other things on the way (study, read, reply e-mails, etc.) (3)**	I would continue using the bus / van / BRT (2); The company that hires me would support me (2)	This value affects my personal expenses, the more I keep using the bus or van (2); I would avoid doing other activities (eg. Shopping, leisure, shopping, etc.) (2); I would use private transport (2)	**I would use private transport (3)**
Central (Both)	**It's cheaper than private transport (3)**	This value would affect my personal expenses, but I would continue using the bus (2); I would stop going by bus, BRT or van (2); I would use private transport (2)	This value affects my personal expenses, the more I keep using the bus or van (2); I would stop going by bus, BRT or van (2); I would use private transport (2); I believe that the Government would subsidize the fare to keep the reduced price (2)	**I would use private transport (3)**
Norte (Both)	**It's cheaper than private transport (3)**	This value would affect my personal expenses, but I would continue using the bus (2)	I would cycle to work (2); I would use private transport (2)	**I would use private transport (3)**
Oeste-Rio (Both)	**It's cheaper than private transport (3)**	**I would continue using the bus / van / BRT (3)**	I would continue using the bus / van / BRT (2); I would use private transport (2)	**I would use private transport (3)**
Jacarepagua (Both)	**I am not satisfied with public transport, but it is the only option for me (3)**	The company that hires me would support me (2)	The company that hires me would bear the increase (2)	I would use private transport (2)
Tijuca (Both)	**It's cheaper than private transport (4); I can do other things on the way (study, read, reply e-mails, etc.) (3)**	I would continue using the bus / van / BRT (2); This value would affect my personal expenses, but I would continue using the bus (2); I would use the train or metro (2); I would stop going by bus, BRT or van (2); I would walk(2);The company that hires me would support me (2)	This value affects my personal expenses, the more I keep using the bus or van (2); I would continue using the bus / van / BRT (2); I would walk (2); I would cycle to work(2); The company that hires me would bear the increase (2); I would do my activities closer to home (shopping, etc.) (2); I would use private transport (2)	I would go by train or metro (2); I would cycle (2); I would do my activities closer to home (shopping, etc.) (2); I would walk (2); I would move closer to the work (2)
Praca_Maua (Both)	**It's cheaper than private transport (4); I can do other things on the way (study, read, reply e-mails, etc.) (3)**	I would continue using the bus / van / BRT (2); I would cycle to work (2)	This value affects my personal expenses, the more I keep using the bus or van (2); I would continue using the bus / van / BRT (2); I would walk (2); I would cycle to work(2); I would look for a job closer to home (2)	**I would use private transport (3)**
Centro (Both)	**I can do other things on the way (study, read, reply e-mails, etc.) (4)**	**I would use private transport (4)**	**I would look for a job closer to home (4)**	**I would use private transport (4)**

Table 54: Variables of the Adaptability Stage of Analysis of the Qualitative Approach – Both Transportation Users – Part 3

Macrozone	Job	Services	Bicycle	Why not cycle?
Sul (Both)	Very difficult: 33% ; Difficult: 33%; Easy: 13%; Very easy: 7%; Do not know: 14%	Easy: 13%; Very easy: 87%;	Yes: 93%; No: 7%	Distance (4); Lack of parking (4); Fear of being stolen (4); Slope (4)
Barra-Recreio (Both)	Very difficult: 30% ; Difficult: 50%; Easy: 10%; Do not know: 10%	Difficult: 10%; Easy: 50%; Very easy: 40%;	Yes: 20%; No: 80%	Distance (4)
Central (Both)	Very difficult: 56% ; Difficult: 33%; Easy: 11%	Difficult: 22%; Easy: 56%; Very easy: 22%;	Yes: 56%; No: 44%	Lack of parking (4); Fear of being stolen (3)
Norte (Both)	Very difficult: 67% ; Difficult: 33%;	Very difficult: 22% ; Difficult: 11%; Easy: 33%; Very easy: 33%;	Yes: 44%; No: 56%	Distance (4); Lack of parking (4); Fear of being stolen (4)
Oeste-Rio (Both)	Very difficult: 78% ; Difficult: 11%; Do not know: 11%	Difficult: 33%; Easy: 56%; Very easy: 11%;	Yes: 67%; No: 33%	Distance (4); Lack of parking (4); Fear of being stolen (4); Climate (3)
Jacarepagua (Both)	Very difficult: 63% ; Difficult: 38%;	Easy: 100%;	No: 100%	Distance (4)
Tijuca (Both)	Very difficult: 50% ; Difficult: 50%;	Difficult: 17%; Easy: 17%; Very easy: 67%;	Yes: 67%; No: 33%	Distance (2); I am not use to cycling (2)
Praca_Maua (Both)	Difficult: 25%; Very easy: 50%: Do not know: 25%	Easy: 75%; Very easy: 25%;	Yes: 75%; No: 25%	Lack of parking (4); Fear of being stolen (4); Slope (4)
Centro (Both)	Very Easy: 100%;	Very easy: 100%;	No: 100%	Distance (4); Lack of parking (4); Slope (4)

In **macrozone Barra-Recreio**, three variables influence the persistence stage of the resilience of urban mobility: destination, transportation mode and time. In relation to the destination, 60% of respondents do not work in the same or neighbourhood macrozone. The transportation mode variable shows that 70% of the respondents use bus, 30% BRT and 20% metro. Regarding the time, 50% of the respondents take more than one hour to reach work.

In the adaptability stage of analysis, eight variables influence on the resilience of urban mobility: reason to use private transportation, the attitude during H2, H3 and H4 threat scenarios of private transportation, the attitude during H3 and H4 threat scenarios of public transportation, job variable and bicycle variable.

The reason for using private transportation is that there is no metro station accessible and because bus takes too long. The attitude when faced with the H2 threat scenario of private transportation shows that some would shift to public transportation, some would continue to use private transportation, shifting fuel to alcohol and some would avoid other activities. In the H3 scenario of private transportation, some would stop using the car and some would continue to use it, shifting to alcohol as fuel. At the H4 scenario, respondents would continue to use private transportation, using alcohol as fuel.

The attitude in the H3 threat scenario of public transportation shows that some respondents would continue to use buses, vans or BRT, although it would affect their personal expenses; some would avoid doing other activities, to save money and some would use private transportation. At the H4 threat scenario of public transportation, most agreed that they would shift to private transportation.

In relation to the job variable, 80% of the respondents believe that it is difficult to find a job in the same or neighbourhood district. Regarding bicycle use, 80% agree that it is not possible to reach a train or metro station by bicycle from their residence.

In **macrozone Central**, six variables influence the persistence stage of the resilience of urban mobility: destination, transportation mode, time, transportation cover and effect of private and public transportation cost on personal expenses. In relation to destination, 40% works in a neighbourhood macrozone and nobody works in the same macrozone where they live. The transportation mode variable shows that 78% of the respondents use bus, 44% metro, 44% train and 22% BRT. The time variable shows that 66% of the respondents take more than one hour to reach work. Regarding transportation cover, 56% of interviewees have to deal totally or partially with transportation costs.

The effect of private transportation costs on personal expenses shows that majority have already sacrificed monthly savings, including basic needs and leisure. In relation to the effect of public transportation costs on personal expenses, majority sacrifice expenses with basic needs and monthly savings.

In the adaptability stage of analysis, seven variables influence resilience of urban mobility: why use private transportation; attitude when faced with H2 and H4 threat scenario of private transportation, attitude faced with H2, H3 and H4 threat scenario of public transportation and job variable.

In relation to the reason why using private transportation, the highlighted affirmations are that "private transportation is more comfortable", "by bus it takes too long" and "I like to go by private transportation". The attitude during H2 threat scenario of private transportation shows that the highlighted affirmations are "I would do my activities closer to home"; "this value would affect my personal expenses, but I would continue to use private transportation" and some would shift the fuel type to alcohol. The H4 threat scenario of private transportation shows that some would shift the fuel type to alcohol.

The attitude when faced with H2 threat scenario of public transportation shows that the highlighted affirmations are "this value would affect personal expenses, but I would continue using the bus"; "I would stop using bus, van or BRT" and "I would use private transportation". The H3 threat scenario follows the same patterns from H2, however adding the belief that the government would act to maintain a reduced price of public transportation. In the H4 threat scenario, most agree that they would use private transportation. Regarding the job variable, 89% of the respondents believe it is difficult to find a job in the same or neighbourhood district.

In **macrozone Norte**, seven variables influence the persistence stage of the resilience of urban mobility: destination, fuel type, transportation mode, time, transportation cover and effect of private and public transportation costs on personal expenses. In relation to destination, 44% of the respondents work in the same or neighbourhood macrozone.

Regarding the destination, 22% works in a neighbourhood macrozone and 22% works in the same macrozone where they live. In relation to fuel type, 56% uses gasoline, 44% alcohol and 11% natural gas. The transportation mode variable shows that 89% of the interviewees use the conventional bus system and 33% uses metro and 33% BRT, therefore presenting a mixed use of transportation modes.

The travel time variable presents that 55% of the respondents take more than one hour to reach work. Furthermore, 55% of the respondents have to deal totally or partially with the transportation expenses, leading to effects on personal expenses, such as with basic needs, leisure costs and savings.

In the adaptability stage of analysis, eight variables influence the resilience of urban mobility: reason why using private transportation, attitude when faced with H2 and H4 threat scenarios of private transportation, attitude when faced with H2, H3 and H4 threat scenarios of public transportation, job variable and bicycle variable.

There is a high level of agreement from most private transportation users that they feel safer in private transportation. Faced with the H2 threat scenario, based on the gasoline price increase, some would shift to public transportation and other would continue to use private transportation, although it would affect their personal expenses. At the H4 threat scenario, some would shift the fuel to alcohol.

At the H2 and H3 threat scenario, based on the increase of oil-based public transportation, it is highlighted that respondents would continue to use buses, vans or BRT systems, and at the H4 threat level, most of respondents would shift to private transportation. Regarding the job variable, 100% of the respondents find it is difficult to find a job in the same or neighbourhood district, while 66% find it is easy to find services in the same area. Furthermore, 56% of respondents believe that it is difficult to reach a train or metro station by bicycle, because of distance, lack of parking, fear of it being stolen and climate conditions.

In **macrozone Oeste-Rio**, six variables influence the persistence stage of the resilience of urban mobility: destination, fuel, transportation mode, time, transportation cover and effect of public transportation costs on personal expenses.

In this macrozone, 22% of the respondents work in neighbourhood macrozones, and no one works in Oeste-Rio. In relation to fuel type, 56% of the respondents use gasoline, 22% alcohol and 11% natural gas. Regarding transportation mode, 89% of the respondents use conventional bus, 67% BRT system and 33% train system. Regarding the travel time, 100% of the respondents take more than one hour to reach work. Furthermore, 67% of interviewees have to deal totally or partially with the transportation costs, leading to sacrifices in personal costs, such as basic needs, leisure and savings.

In the adaptability stage of analysis, five variables influence the resilience of urban mobility: reason why using private transportation, the attitude when faced with H2, H3 and H4 threat scenario of public transportation and job variable.

In relation to the reason why using private transportation, most respondents agreed that public transportation is uncomfortable, by bus it takes too long, BRT system being full and there is no metro accessible. Regarding the threat scenarios, in H2 and H3, respondents would continue to use buses, vans or BRT and in the H4 scenario, respondents would shift to private transportation. Furthermore, most of the respondents of this macrozone believe it is difficult to find a job in the same or neighbourhood district from where they live.

In **macrozone Jacarepagua**, four variables influence the persistence stage of the resilience of urban mobility: income, transportation mode, time and transportation cover. Respondents who earns until two minimum salaries consist of the 50%. Regarding transportation mode, 100% of the respondents use the conventional bus system, 25% BRT and 25% metro. In relation to the time of travel, 50% of the respondents take more than one hour to reach work. Furthermore, 50% of interviewees deal totally or partially with the transportation costs.

In the adaptability stage of analysis, nine variables influence the resilience of urban mobility: reason why using public and private transportation, the attitude when faced with H2 and H4 threat scenario of private transportation, the attitude during H2, H3 and H4 threat scenario of public transportation, job variable and bicycle variable.

The reason why using private transportation in this macrozones is related to the uncomfortable public transportation, no accessible metro station, BRT system being full and by bus it takes too long. For public transportation, most of the respondents agreed that public transportation is the only option, although they are not satisfied with the service.

Regarding the attitude during the H2 threat level, related to private transportation use, the highlighted affirmations are that respondents would feel financially affected. However, they would continue to use private transportation. At the H4 level of threat, some would shift the fuel use to alcohol.

For the attitude during the public transportation threat levels, in the H2 and H3 scenarios, respondents would continue the same pattern of transportation, believing that the company that hires them would support the increase of price of oil-based public transportation. At the H4 scenario, most respondents would shift to private transportation use.

Furthermore, most of respondents believe that it is difficult to find a job in the same or neighbourhood district from where they live and that it is not possible to reach a train or metro station by bicycle, because of the distance.

In **macrozone Tijuca**, three variables influence the persistence stage of the resilience of urban mobility: fuel, transportation mode and transportation cover. Regarding the fuel type, 67% of respondents use gasoline, and 50% uses alcohol as fuel. In relation to transportation mode, 83% of respondents use the conventional bus system, while 50% uses metro. Furthermore, 50% of respondents have to deal totally or partially with the transportation costs.

In the adaptability stage of analysis, three variables influence the resilience of urban mobility: reason why using private transportation, attitude when faced with H3 threat scenario of public transportation and job variable.

The reason why using private transportation is related to the unreliability on the conventional bus system. Regarding the H3 threat level, related to public transportation use, some respondents would feel financially affected; some would continue to use the conventional bus system and others would shift to private transportation use. Furthermore, 100% of the respondents believe that it is difficult to find a job in the same or neighbourhood district.

In **macrozone Praca_Maua**, six variables influence the persistence stage of the resilience of urban mobility: income, fuel, transportation mode, time, transportation cover and effect of public transportation cost on personal expenses.

The income variable shows that 50% of respondents earn until two minimum salaries. The fuel variable presents that 50% of the respondents use gasoline as fuel, 25% alcohol and 25% natural gas. Regarding the mode of transportation, respondents who use the conventional bus system are 100% and 25% uses BRT, metro and train. In relation to travel time, 50% of the respondents take more than one hour to reach work. Furthermore, 75% of respondents have to deal totally or partially with transportation costs, leading to effects on personal costs, such as basic needs, leisure and savings.

In the adaptability stage of analysis, five variables influence the resilience of urban mobility: reason why using private transportation and attitude when faced with H2, H3 and H4 threat scenarios of public transportation.

Most of the respondents agreed that private transportation is more comfortable. Regarding the attitude during H2 and H3 threat scenarios related to public transportation, the highlighted affirmations are that respondents would continue to use buses, vans or BRT systems and that this value would affect personal costs. At the H4 threat level, most of respondents would shift to private transportation.

In **macrozone Centro**, four variables influence the persistence stage of the resilience of urban mobility: destination, transportation mode, time and transportation cover. Regarding destination, no respondent works in the same or neighbourhood macrozone. The transportation mode variable shows that 100% uses the conventional bus system and takes more than one hour to reach work. Furthermore, there is no cover of transportation costs, leading to effects on personal costs, related to leisure and others.

In the adaptability stage of analysis, six variables influence the resilience of urban mobility: reason why using private transportation, attitude face to H2 and H4 threat scenarios of private and public transportation and bicycle variable. Despite transportation costs already affecting personal expenses, the interviewees prefer to use private transportation. In the H2 and H4 scenario threats, of public and private transportation, there is a trend to continue using private transportation, shifting to alcohol as fuel. Furthermore, the respondents agree that it is not possible to reach a train or metro station by bicycle, because of distance, lack of parking and slope conditions.

8.4. Transformability Evaluation

This stage of evaluation involves the perspective of transportation users (1) professionals, researchers (2) and the government (3).

8.4.1. Transportation Users Perspective (Questionnaire)

For this section, the element of social movement is evaluated under the perspective of the users of the transportation systems. The analysis of this element is based on two questions: "Do you believe that social movements can generate an improvement on urban mobility"; "Have you ever participated in a type of social movement (e.g. protests, demonstrations, etc.)?"

The types of transportation users (private, public and both) are discussed in this section. Starting from the public transportation users, Figure 86 shows the answers in relation to the question analysed here. In all the macrozones, more than 50% public transportation users believe that social movements can improve urban mobility. Four macrozones have less than 50% users who participated in protests and demonstrations, which are Barra-Recreio, Central, Norte and Oeste-Rio.

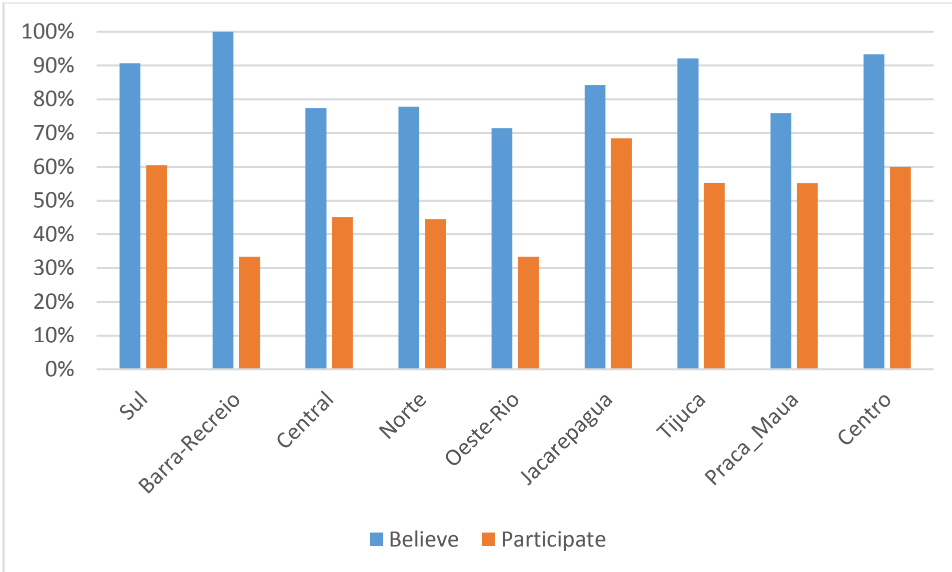


Figure 86: Percentage of responses related to whether interviewees believe that social movements can improve urban mobility and if they ever participated in one (Public transportation users)

Figure 87 shows the social movement data of the both transportation users. The data shows that in all macrozones, more than 50% respondents believe that social movements can improve urban mobility. On the other hand, there are five macrozones that 50% or less respondents have already participated in protests or demonstrations, which are Sul, Barra-Recreio, Norte, Oeste-Rio and Tijuca.

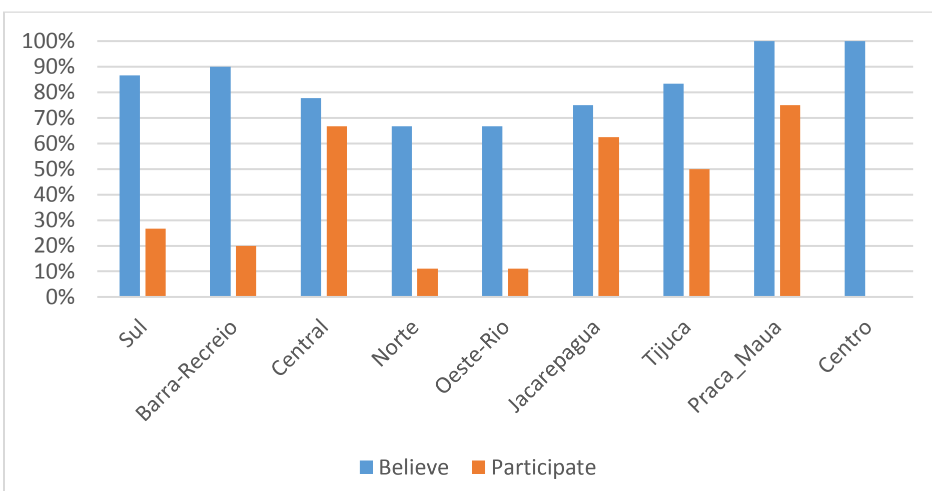


Figure 87: Percentage of responses related to whether interviewees believe that social movements can improve urban mobility and if they ever participated in one (Both transportation users)

Figure 88 shows the social movement data of the private transportation users. There are three macrozones where 50% of the respondents believe that social movements can improve urban mobility. There are eight macrozones where 50% or less respondents have already participated in a protest and demonstration. They are Sul, Barra-Recreio, Central, Norte, Oeste-Rio, Jacarepagua, Tijuca and Praca_Maua.

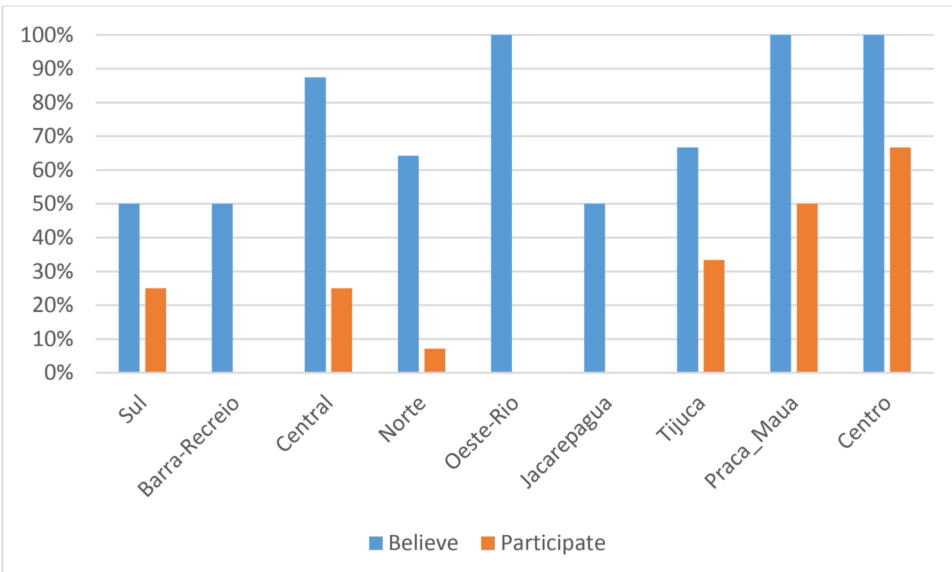


Figure 88: Percentage of responses related to whether interviewees believe that social movements can improve urban mobility and if they ever participated in one (Private transportation users)

For public transportation users, the macrozones with low level of transformability are as follows: Barra-Recreio, Central, Norte and Oeste-Rio. For both transportation users, the macrozones with low level of transformability are as follows: Sul, Barra-Recreio, Norte, Oeste-Rio and Tijuca. For private transportation users these are as follows: Sul; Barra-Recreio; Central; Norte; Oeste-Rio; Jacarepagua; Tijuca and Praca_Maua.

In general, to put in an order, from better to worse, in relation to the groups of users that have higher participation in protests and demonstration, the order is public transportation users, both transportation users and private transportation users.

8.4.2. Professionals and Researchers Perspective (Interview)

This section analyses the interviews conducted with professionals and researchers in the field of transportation and urban development. The elements analysed in this section are the role of the public sector, social movements and right to urban mobility. Furthermore, the analyses are divided in groups of interviewees, researchers, professionals and government perspectives.

8.4.2.1. Public Sector (Policies and Projects)

The base question in this section is "Are there, currently, policies or projects encouraging the reduction of fossil fuel use in the transportation sector in the city of Rio de Janeiro?"

Table 55 shows the perspective of researchers on the question related to the public sector. There are two interviewees (1 and 3) that there is no large-scale project to reduce the fossil fuel use. The other two interviewees (8 and 10) believe that there is no action in this direction. The projects cited that can reduce the fossil fuel use are those related to encouraging bicycle use, however interviewee 1 affirms that encouraging bicycle use is a solution for small-scale trips.

Table 55: Researchers' perspective on "Are there, currently, policies or projects encouraging the reduction of fossil fuel use in the transportation sector?"

Interviewees	**Quote from the interview**
Interview 1: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	"No. You see people talking about encouraging bicycle use and walking trips...however this is for a smaller scale."…"There are distance levels that people will still need to use motorized transportation."
Interview 3: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	"No. There are some policies that favor, those related to non-motorized trips, as increasing the bicycle ways. However, I do not know if, in fact, there is this perception, if they are thinking about this (reducing fossil fuel use)"
Interview 8: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	"I continue to think that there are none at the moment, a movement that convinces me, that they are committed. I do not see this as a concern of the State Government"
Interview 10: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	"I think they consider, because the world wants this. However, objectively, what we see is the construction of new corridors (for motorized transportation). In practice, we do not see any action in this direction"

Table 56 shows the perspective of the professionals who work in the field of transportation. Two interviewees (4 and 6) believe that there are guidelines and legislations that favour the reduction of fossil fuel use in the transportation sector, however the actions in this direction are not relevant. Interviewee 7 affirms that at the government level, there is no action to encourage the reduction of fossil fuels, but the bus companies try to stay aware of the new technologies. Interviewee 11 says that there is no concern with this issue.

Table 56: Professionals' perspective on "Are there, currently, policies encouraging the reduction of fossil fuel use in the transportation sector?"

Interviewees	Quote from the interview
Interview 4: M.Sc – Coordinator of Transportation Projects at ITDP – NGO – Focus on BRT	"I think so. There are guidelines in this direction. But consider it is one thing, and put it into practice is another thing, there is still this difference"
Interview 6: M.Sc – Private consultant on Sustainable Transportation	"In the legislation we start to notice this trends and guidelines, however the implementation of the action is too experimental. If we look to the projects that include alternative fuels, they still has a light weight, in comparison to the regulation policies that pressure the reduction of atmospheric pollution in the city."
Interview 7: M.Sc – Executive President of the RioOnibus and Fetranspor – The Unions of The Bus Companies	"At the government level, I do not see any action, neither at Federal, neither at State and neither at Municipal scale. There is an effort of the operators to test new fuel, and make it feasible"… "we participate in international semminares"… "we try to follow and bring new technologies, but from the government I do not see any initiative to encourage (this)"
Interview 11: M.Sc – Consultant at FGV Projects	"I would say no, there is not yet this concern"… "If you do not have this concern today, certainly, in 20 years you will not reach anywhere"

Table 57 shows the perspective of the government. One of the interviewees (2) believes that there is no project to reduce the use of fossil fuels, while the other (5) believes that there have been very small initiatives, furthermore, they do not involve public transportation.

Table 57: Government's perspective on "Are there, currently, policies encouraging the reduction of fossil fuel use in the transportation sector?"

Interviewees	Quote from the interview
Interview 2: M.Sc – Architect at the City Hall – Focus on Urbanization of Poor Areas	"I do not see this"
Interview 5: M.Sc – Geographer at the City Hall – Focus on Urban Planning	"Very little. I see some initiatives with electric taxis, cycle ways, which maybe are the major ones. However I do not see this with public transportation"

In general, the researchers believe that the government of Rio de Janeiro has low or no concern regarding the reduction of the use of fossil fuels in the transportation sector, leading to non-representative projects or policies. From the professionals' perspective, it is observed that there is a legislation and guidelines that should encourage the reduction of fossil fuel use. However, in practice, there are only feeble actions in this direction. From the government's perspective, there is none or very little initiative in reducing the use of the resource in discussion.

8.4.2.2. Social Movements and Right to Urban Mobility

The basic questions for this section are: "are there initiatives on the transportation planning process, to consider the participation of the users" and "do social movements generates influences on the improvement of urban mobility?" The first question is related to the element of right to urban mobility and the second question is related to social movement.

Table 58 shows the perspective of researchers on the questions adressed in this section. In relation to the right to urban mobility, under the view of the participative process on transportation planning, the respondents affirm that there is still none or low participation. It seems that the law requires this participation. However, in practice, it does not happen or it is not done properly. Regarding the element of social movements, the respondents of Table 58 still believe they have a low influence on improvements or changes in urban mobility.

Table 58: Researchers' perspective on "Are there initiatives on the transportation planning process, to consider the participation of the user?" and "Do social movements generates influences on the improvement of urban mobility?"

Interviewees	Elements	Quote from the interview
Interview 1: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	Right to urban mobility	"If the answer is yes or no, they hear (the population), but if it is the proper way, I would say no. It is a low participation (in general)."
	Social movements	"I do not know, it should influence."
Interview 3: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	Right to urban mobility	"It is a totally necessary (participative planning). No (it does not exist)"
	Social movements	"Low influence. The social movements of 2013 got to freeze the price of the fare (bus) for a while, but what was the improvement in fact, none."
Interview 8: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	Right to urban mobility	"I see this issue as you have a law requiring the participation of the public, in practice, I see this as unlikely."
	Social movements	"I do not see a consistent and sistematic structure, discussing this in a mature way. So, the initiatives were punctual, in a favorable environment in a certain moment…but it is not consistent"
Interview 10: Professor Dr. – Transportation Engineering Program – Federal University of Rio de Janeiro	Right to urban mobility	"Does not exist the participation of the (transportation) user on the process, here in Rio. What is the chanel? Does not exist. Major part of this univerve, which we call user and poor people depend on the buses"
	Social movements	"I think it is still low. For the need that we have, it is low."

Table 59 shows the perspective of professionals. From this data, in relation to the right to urban mobility, all of the respondents affirm that there is a low level of participation in the planning process in the transportation sector. It can be highlighted that interviewee 7, who is an executive president of the Union of bus companies, affirms that he does not see participative planning with good eyes, because he believes that people tend to focus more on individual interests than collective ones.

Regarding the social movement element, all of the respondents agree that there is low influence of social movements on the improvement of urban mobility. Interviewee 4 said that the recent social movement was a trigger for the discussion about urban mobility. Interviewee 6 affirms that the changes are still slow. Interviewee 7 affirms that there is a lack of canalisation and structure in the social movements. Interviewee 11 believes that recent protests generated a higher charge of the transportation operators, from population, but still with a low level of influence on urban mobility.

Table 59: Professionals' perspective on "Are there initiatives on the transportation planning process, to consider the participation of the user?" and "Do social movements generates influences on the improvement of urban mobility?"

Interviewees	Elements	Quote from the interview
Interview 4: M.Sc – Coordinator of Transportation Projects at ITDP – NGO – Focus on BRT	Right to urban mobility	"No participation. There is a process of punctual hearing. But the participation, conceive together, hear and modify."
	Social movements	"It is important, since the work is not disperse. It has to be structured. Contributed more as a trigger…than as a change it self."
Interview 6: M.Sc – Private consultant on Sustainable Transportation	Right to urban mobility	"It is still low, because you reach a small amount of the population, which are the empowered population that are already inserted in the process…In Zona Sul…the residents are more organized…In Zona Norte, you have a population less used to be inserted in the (participation) process."
	Social movements	"They have influenced. A social movement, like the one in June 2013…it is nice to see the engagement. The changes are felt slowly."
Interview 7: M.Sc – Executive President of the RioOnibus and Fetranspor – The Unions of The Bus Companies	Right to urban mobility	"I do not see this with good eyes. Because the perspective of the user is more related to the personal interest, and not the collective, not the perspective of the city, he does not have the knowledge and technical basis of this broad view. Low participation."
	Social movements	"I understand that the social movement that happened was related to a broad dissatisfaction, more than only the fare price, or free passage….I believe that there was a lack of canalization (of the movement)". "There is a low influence"
Interview 11: M.Sc – Consultant at FGV Projects	Right to urban mobility	"Exists, but in fact if this influences planning, I think not. I believe there are, maybe, many people complaining about specific measure… However, this is not a part of the methodological procedure of planning and operation the service. So, I believe that the vision top-down, imposing, does not work well."
	Social movements	"Yes. I believe that there was a change, which is a higher charge. This charge about the monopolies of the transportation companies, demonizing the operators. Low influence."

Table 60 shows the perspective of government employees about the right of urban mobility and social movement elements. In relation to the right to urban mobility, one of the interviewees (2) said that he does not see participation, because it is not characteristic of Rio de Janeiro administration. The other cited a recent project, called AGORA, which attempts to include people in the process of planning.

Regarding the element of social movement, interviewee 2 highlighted the bicycle movement, but nothing beyond that. Interviewee 5 points out that the recent protests, in 2013 and 2014, had a symbolical impact, not a practical one.

Table 60: Government's perspective on "Are there initiatives on the transportation planning process, to consider the participation of the user?" and "Do social movements generates influences on the improvement of urban mobility?"

Interviewees	**Elements**	**Quote from the interview**
Interview 2: M.Sc – Architect at the City Hall – Focus on Urbanization of Poor Areas	Right to urban mobility	"I do not see participation. This is not a characteristics of Rio de Janeiro, with a conservative administration"
	Social movements	"There are the bicycle movements. I do not see much movements with the focus on improving transportation."
Interview 5: M.Sc – Geographer at the City Hall – Focus on Urban Planning	Right to urban mobility	"This is new, but recently…there is AGORA, a new platform of public participation, which started 3 or 4 years ago."
	Social movements	"I think yes, there was an impact in 2013 and 2014. It did not grow…In fact it did not have any impact, but a symbolical impact."

Overall, the researchers' perspective on the right to urban mobility shows that there is a low participation of the transportation users in the planning process, although this requirement is present in the legislation. The professionals also affirmed that there is low participation of the users in the planning process. From the perspective of the government employees, one affirms that he does not see participation and the other cited a recent project of the government of Rio de Janeiro, called AGORA. The general perspective on the social movement shows that there is a low influence of protests and demonstration on the improvement of urban mobility.

8.4.3. Municipal Perspective

This section focusses on the analysis of the most voted projects on the AGORA report from the government of Rio de Janeiro. This report is based on a recent project, which worked through an online platform for discussion and policy proposition with the participation of the public at the City Hall of Rio de Janeiro. This project started in September 2014, with the discussion about the Olympics, and in 2015 they included the discussion of urban mobility, which is the one discussed in this section (Government of Rio de Janeiro, 2015).

Table 61: Transportation projects voted by the public (Government of Rio de Janeiro, 2015)

Ranking	Projects	Votes	Description
1	Restructure the city bus system	1920	Perpetuates the bus use – focussing on the redesign of bus lines
2	Execute water transport projects in the city	1213	Although water transportation carries more people, it is still fossil fuelled and the most expensive modal
3	Improve infrastructure for cyclists	1184	Implementation of changing rooms and showers; new bicycle parking facilities in transportation stations and spaces occupied by cars
4	Improve the bus fleet in circulation	1173	Although there can be an increased supervision of the already existing requirements, it perpetuates the bus use
5	Improving sidewalks	1128	Improvement of sidewalk infrastructure and security
6	Creating quality standards for the bus stops and public transport stations	1099	Improvement of comfort and trust in the public transportation system
7	Expand Cycleway`s system	1093	Improvement of the connections of cycleways to BRT, train and metro stations
8	Review and unify the Single Ticket systems	1086	Development of a single ticket including bus, BRT, metro, train and tram
9	Create an integrated system of information on urban mobility	1027	Development of accessible information to facilitate the use of public transportation
10	Increase the security of walking and cycling trips	1020	Stimulate the walking and cycling trips (infrastructural and technical changes)
11	Integrating neighbourhoods separated by railways or BRT system	876	Facilitated the pedestrians crossing between two sides of a railway or BRT system
12	Facilitate the registration, purchase and recharge system for the Single Ticket	856	Stimulates the use of the single ticket
13	Create an integrated inspection system for urban mobility	818	Controlling quality of service
14	Create more space for pedestrians	745	Transform parking lots and empty spaces in leisure areas
15	Create alternative access to Ilha do Fundao, Governor's Island and Galeao Airport	723	Extend the BRT and Water Transport Connection
16	Revitalizing part of Av. Presidente Vargas (Central / Candelaria)	722	Improve public lighting with the intention of improving security and create recreational areas for the weekends
17	Create an integrated management system for urban mobility	670	Increase the participation of the population in the planning process
18	Reduce the circulation of cars in city areas (Toll Urban Pilot Project)	540	Create taxes to circulate by car in some city areas and invest in public transportation
19	Develop an educational plan on mobility in schools	535	Raise awareness about people's rights, good behaviour and sustainable mobility
20	Reduce parking in public spaces	501	Reduce parking lots in public spaces and encourage "home office" practice in the public and private sector
-	Total participants	2.775	-

Table 61 shows the 20 projects selected as focus-future projects to be implemented in the next few years in Rio de Janeiro. It is important to highlight that the process started by a proposition of projects from the public, then a group of experts selected the most important. Afterwards, the projects were put to a vote. From this perspective, the voted projects were filtered by the government, to find what they believe is more important for the city.

Starting from the top 10 projects, those that encourage, more directly, the reduction of fossil fuel use is related to bicycle use (project 2, 7 and 10). The focus on these projects involve implementation of changing rooms and showers, new bicycle parking facilities, extended cycleways to reach metro and train stations and improved quality of the cycleway infrastructure to bring more security. Other projects, within this top 10, which stimulates the reduction of fossil fuel use, are related to water transportation and sidewalks improvements. Usually, water transportation can carry more people than a bus; this could reduce the consumption of fossil fuel partially. Improving sidewalk can encourage people to walk more, however trips by foot have a smaller scale of reach, in comparison to bus, metro, train and other transportation systems.

Between the 10 and 20 in the ranking of projects, those that encourage the reduction of fossil fuel use are related to stimulating walking trips and the use of public transportation. This also includes integration of districts separated by railways or BRT systems, by creating more space for pedestrians, charging extra cost to use the car in central areas of the city, raise awareness about sustainable mobility and facilitate the buying of integrated tickets to use for public transportation.

Figure 89, Figure 90 and Figure 91 show the transportation projects that were and will be implemented along time, until 2020. This data was collected from a research group of the Federal University of Rio de Janeiro, which developed a project named MobiRio. In this project, all transportation projects of the metropolitan area of Rio de Janeiro that were implemented and those in progress are included.

Figure 89 shows the evolution in time regarding the metros, trains, cable cars and inclined plane systems in the city of Rio de Janeiro. Firstly, we observe that the urban train systems did not undergo any changes in the last ten years. The metro was extended, between 1998 and 2015, to macrozones Tijuca, Sul, Praca_Maua and Norte. Between 2016 and 2020, this system will be extended to macrozone Barra-Recreio. Besides the extension of the metro system, in the last ten years, two cable car systems were implemented, one in Praca_Maua and the other in Centro. They intend to facilitate greater access for the low social classes to the metro and train systems. Furthermore, two inclined plane systems were implemented for the same reason, one in macrozone Norte and the other in Sul.

Figure 90 shows the evolution in time of the tram system in Rio de Janeiro. It can be observed that although there is an extension project for the tram, which improves the connection of this system to other modal choices (metro, urban train and bus), it only attends the Centro macrozone for those that are moving in this area. Furthermore, there is no tram project for the other macrozones.

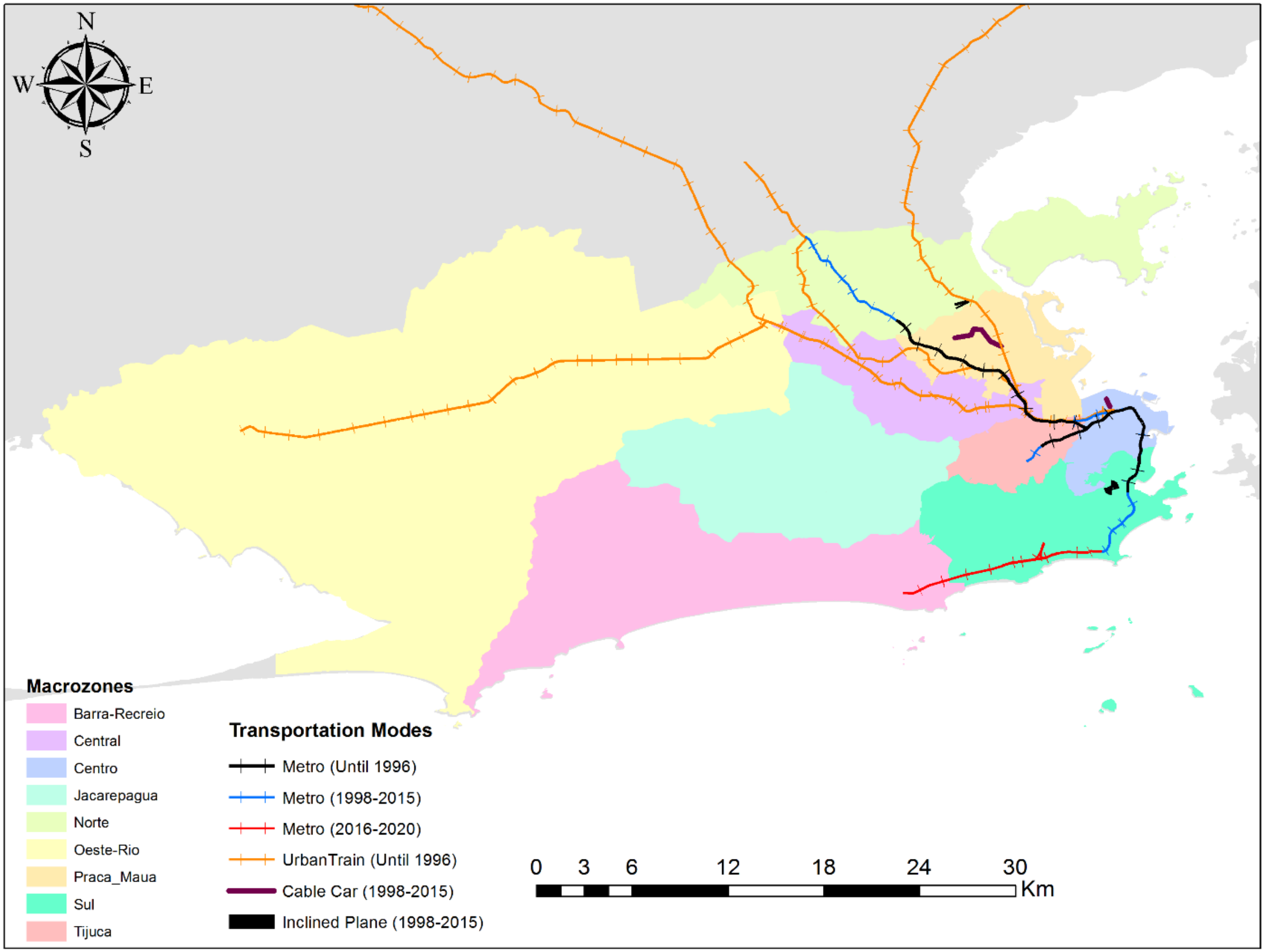


Figure 89: Metro, Urban Train, Cable Car and Inclined Plane projects in time (MobiRio, 2014)

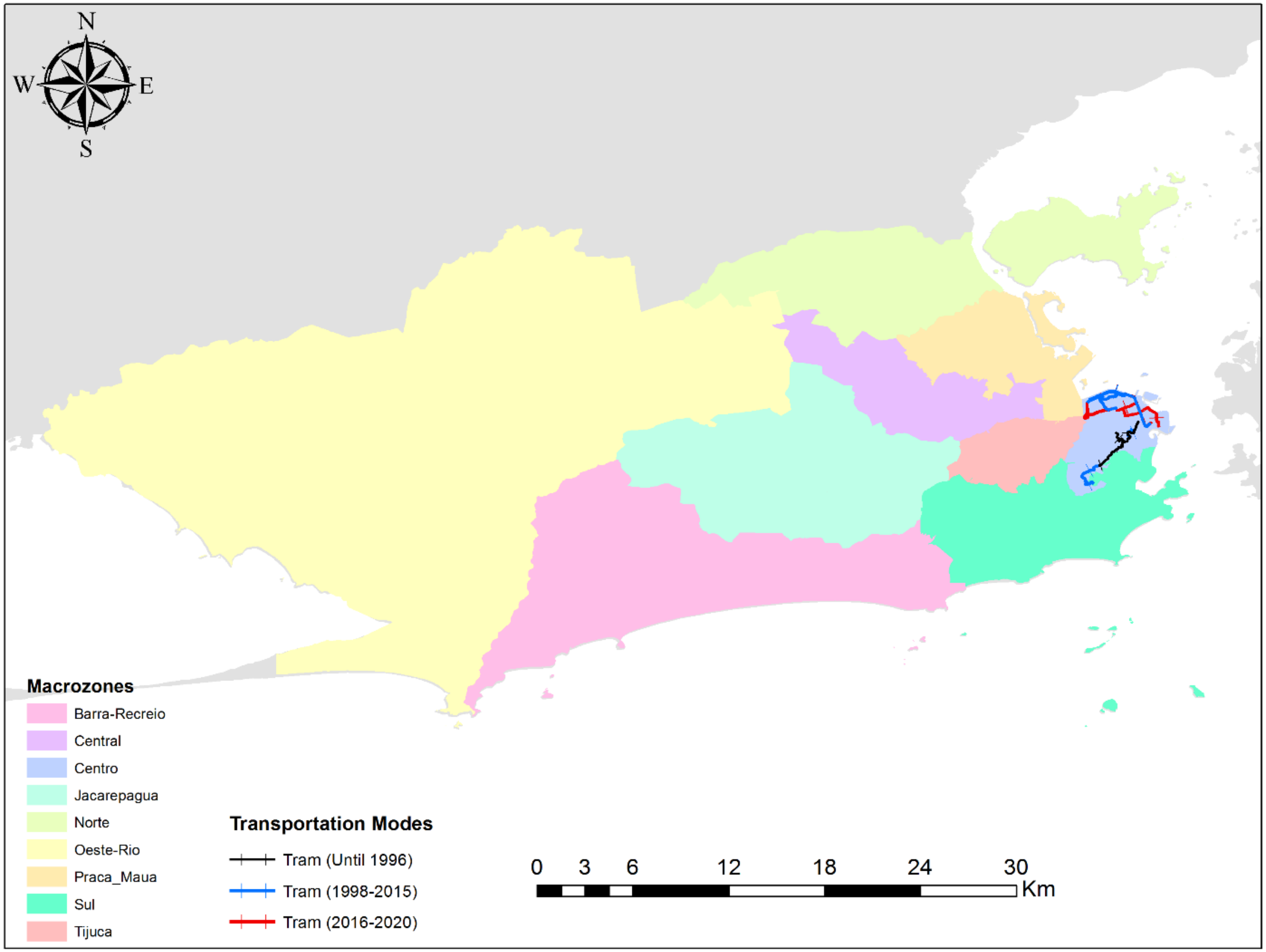


Figure 90: Tram projects in time (MobiRio, 2014)

Figure 91 shows the evolution in time of the BRT system in Rio de Janeiro. Firstly, ten years ago, there were no BRT systems in place. These projects, initially, involved macrozones Norte, Praca_Maua, Central, Jacarepagua, Barra-Recreio and Oeste-Rio. In the next few years, the BRT will be extended in macrozones Norte, Oeste-Rio, Praca_Maua and Centro. The entire project involves 97 kms of BRT infrastructure, while the metro system will have approximately 73 kms, with all implemented projects, and the urban train has approximately 118 kms within Rio de Janeiro. BRT is a recent project in comparison to urban train and metro in the city.

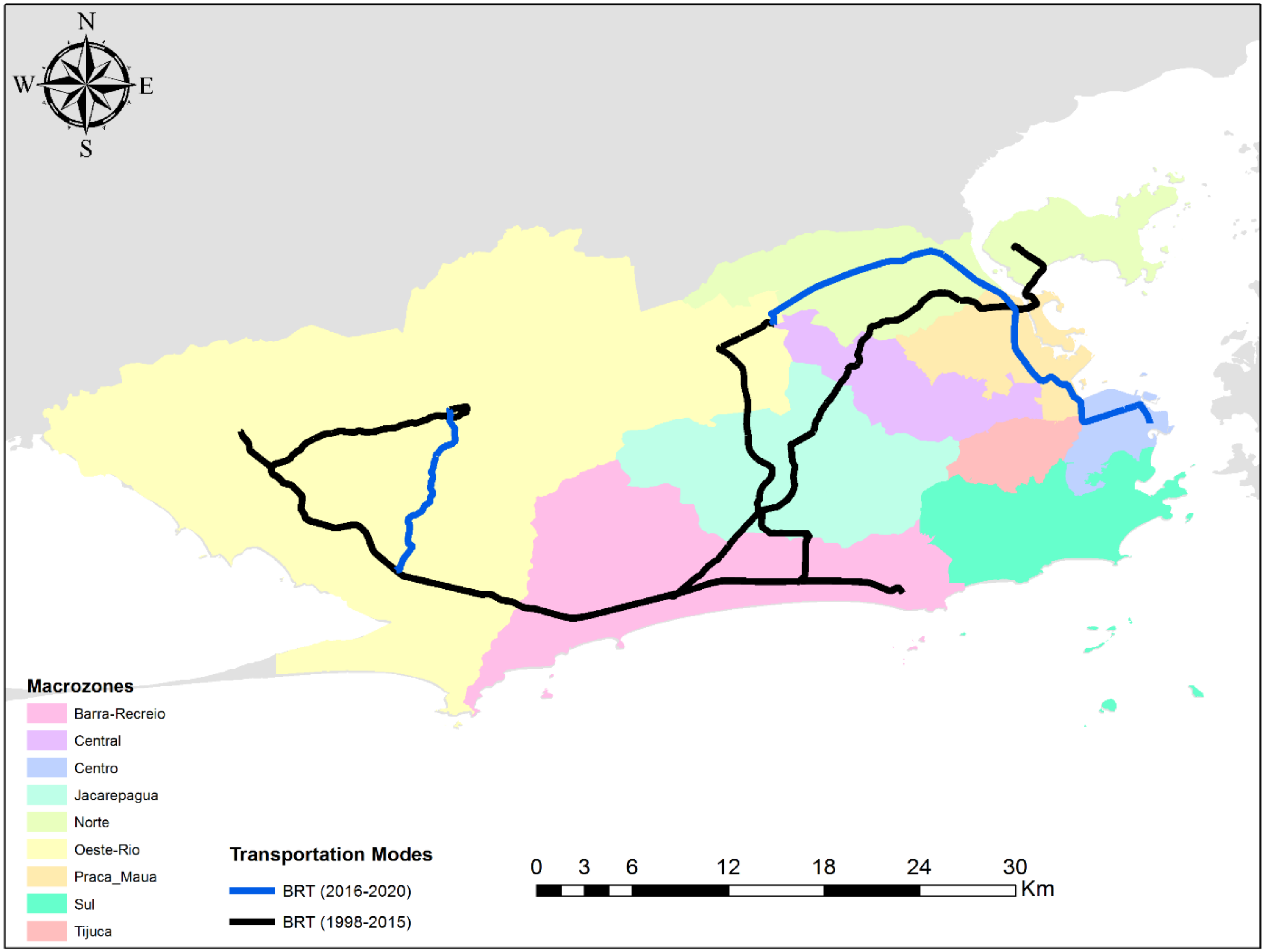


Figure 91: BRT projects in time (MobiRio, 2014)

As a general view of the transportation projects, it is possible to observe that macrozones Jacarepagua, Central and Oeste-Rio are the only ones that did not receive new projects of electric-based transportation systems in the last 20 years. Accessibility transportation systems, such as cable car and inclined plane, were built in macrozones closer to the Centro macrozone. With regard to the tram system, it was extended in macrozone Centro, with the intention to facilitate the movement in this area as well, with the intention of reducing the car use in this macrozone.

In relation to the BRT system, it was implemented initially in macrozones that have difficulty in accessing train or metro stations and with higher number of families with lower income. Furthermore, this project encourages the multi-modal use, connecting the BRT systems to metro and train stations. However, it can be highlighted that the prices to combine BRT with metro or train are higher than using only the BRT or conventional bus systems. The BRT-metro combination price is 46% higher than BRT-BRT/bus combination, and BRT-urban train is 36% higher. Furthermore, the BRT-metro and BRT-train are also more expensive than only train or metro price.

From these projects and the current context, there is a high possibility that people from macrozones Barra-Recreio, Jacarepagua and Oeste-Rio need to take more than one transportation mode on their way to work, leading to higher expenses with transportation. Although macrozone Central did not receive new projects in the last few years, it has two urban train lines passing through this area, increasing consequently, the accessibility to this transportation mode.

In addition to this analysis of projects, problems observed in a recent report financed and published by the municipal government of Rio de Janeiro (Prefeitura do Rio de Janeiro, 2015) have been included. This report addresses the transportation system and mobility in Rio de Janeiro, focussing on problems and opportunities to improve the current urban mobility context. The final observations of the report are presented in Table 62, dividing information in negative and positive aspects related to social, urban and transportation aspects.

Table 62: Negative and positive aspects in each Macrozone – Urban and Socioeconomic aspects (Prefeitura do Rio de Janeiro, 2015)

Macrozones	Negative	Positive
Centro (AP-1)	- Imbalance of population and jobs - Expanding slum areas - High amount of disabled buildings - High quantities of bus operating and private transportation	- High offer of public transportation - Implementation of the project *Porto Maravilha*
Sul (AP-2) Tijuca (AP-2)	- Saturated road system; - Complex social structure (high level of social inequality); - Urban degradation because of the slum proximity; - Irregular occupation of slope areas.	- High offer of public transportation - Implementation of cycleways and public bicycle project; - Project to urbanise slum areas;
Central (AP-3) Praca_Maua (AP-3) Norte (AP-3)	- Lack of green and cultural areas; - High amount of slums; - Safety problems near slum areas (in terms of accidents); - Districts separated by railways; - Deactivated industrial complexes; - Abandoned road construction sites that have been invaded by irregular occupation	- BRT project; - High public transportation accessibility, with the need of investments and urban renewal; - Revitalization of areas near railway lines; - Area with concentrated mixed land use; - Transformation of industrial complexes for more dynamic uses
Jacarepagua (AP-4) Barra-Recreio (AP-4)	- Dependency on private transportation; - Hard to access by foot the public transportation system; - Concentration of gated communities, generating high level of traffic; - Geographical characteristics difficult for urban development; - Strong influence and investment of the real estate market in this area; - Increasing social segregation and slum expansion	- Extension of the metro system to this area; - Increasing bicycle paths; - BRT implementation; - New highway in the area; to access the north part of the city; - Attraction of new economic activities, to decentralise the city from the CBD area (macrozone Centro).
Oeste-Rio (AP-5)	- Precarious public transport system - Lack of footbridge to cross large avenues; - Penitentiary and waste landfill affect the structuring of urban space; - Precarious public facilities; - Residential areas disconnected from public services and urban areas; - Invasion of public and private properties for irregular occupation; - The project MCMV are located in areas with no jobs, which generate long distance trips	- BRT project; - Industrial site; - Construction and renewal of avenues to access Barra-Recreio macrozone; - Implementation of residential areas for low-income families (Project MCMV);

From Table 62, it is possible to observe that each macrozone or group of macrozones has different set of problems. Firstly, it is observed in the data and agreed in the report (resumed in Table 62) that the jobs are centralised. In other words, there is weak project of decentralising the jobs in the city. The largest current effort is to stimulate the economic growth of macrozones Jacarepagua and Barra-Recreio, attracting companies to these macrozones, by public investments in urban infrastructure, transportation and public services. Coincidentally, these macrozones have the strongest influence of the real estate market in the city and has the highest rates of private transportation use.

Macrozones Centro, Sul and Tijuca, historically, have received more investments in urban infrastructure and transportation. Hence, these areas accommodate higher income families, economic activities and higher diversity of transportation modes. According to the report in question (utilized to build Table 62), macrozones Centro, Sul and Tijuca are the ones with higher demand for non-motorised transportation, because there are higher rates of short distance trips. For this reason, the government has been investing strongly in comparison to other macrozones, on cycling pathways and renting-bicycle projects.

Macrozones Central, Praca_Maua and Norte concentrate a higher amount of slums, in comparison to other parts of the city and have higher population density. This could be explained by the better accessibility and proximity to the CBD area of the city, because of the presence of metro and train systems and the lack of incentive for a local economic development for a long period, generating devaluation of land and low level of government control and investments. However, since 1993, the government has been investing in infrastructural improvements in some districts of these macrozones (Central, Praca_Maua and Norte). Instead of improving social conditions, these changes have been strengthening the social inequality, because of punctual urban improvements, generating spatial restriction for low-income population (Oliveira, 2008). Furthermore, although, these macrozones present mixed land-use characteristics, generating distributed job positions within the districts, the average wage of these three macrozones together are the second lowest, after macrozone Oeste-Rio (Prefeitura do Rio de Janeiro, 2015).

Macrozone Oeste-Rio concentrates a higher number of low-income families, and a context of long distance trips. Furthermore, this macrozone presents precarious transportation conditions. Although there is an urban train in this area, this transportation system presented technical problems for a while (Rodrigues, 2016), influencing, with some frequency, the disruption of the operation. The government of Rio de Janeiro is making an effort to control and improve the maintenance of the urban train system, to improve the quality of the service (Rodrigues, 2016). The other option of public transportation in this macrozone is the conventional buses and BRT systems. Significant number of BRT routes in this macrozone has no exclusive pathways for this system. It contradicts the concept of Bus Rapid Transit and generates more time spending trips with the mixture of this system in normal traffic. This situation was seen by the author of this thesis in a field trip on December 1, 2015. Furthermore, the project to build housing areas for low-income families has been locating families in areas where it is difficult to access urban services and public transportation (Table 62).

In terms of transformability, each part of the city has been changing in different ways and following different logics. In relation to preparing the city in case of fossil fuel threats, it is understood that macrozones Centro, Sul, Norte, Praca_Maua and Barra-Recreio received new electric-based transportation modes, which reduce the dependency on fossil fuels. In relation to job positions, the city presents a concentration of job positions in macrozones Centro, Sul, Praca_Maua, Barra-Recreio, Central, Tijuca and Norte. Concerning the urban structure and public services, macrozones Centro, Sul and Tijuca present better conditions compared to other parts of the city, leading a favourable environment for walking and cycling trips.

Historically, the macrozones near Centro, plus macrozone Barra-Recreio, have been receiving more investments and significant urban and transportation improvements. The efforts are put in because macrozones Norte, Jacarepagua, Central and Oeste-Rio are evident of the social inequality and accessibility problems to basic services, and the life quality of all social classes needs to be improved.

8.5. Level of Resilience of Urban Mobility of Rio de Janeiro: Combinations of the Quantitative and Qualitative Results

This section intends to present the results regarding the resilience of urban mobility of Rio de Janeiro, considering all three stages, persistence, adaptability and transformability. This part of the work considers both the qualitative and quantitative approach, with the intention of the results to reach as close as possible to the reality. Based on interpretation of the collected and analysed data in both approaches, the results were scaled between strong points (10 – ten) and weaknesses (0 –

zero), then an average is done using all data from each group of analysis, generating a result in the same scale. Furthermore, there are four groups of analysis, which is based on a quantitative approach using data from the Brazilian Institute of Geography and Statistics (IBGE) and from the municipality of Rio de Janeiro, and the others are based on qualitative approach, where data are gathered through the application of questionnaires. For the qualitative approach, three groups are analysed, the public, private and both transportation users.

The results for each stage of analysis are the results of the four groups that are gathered and levels of resilience for each stage are generated as shown in Table 63. From this logic, for each resilience stage there is a result. Furthermore, gathering the results from all resilience stages is based on the summing up of all the results from all the stages and scaling the results from zero to four and determining a final level of resilience of urban mobility. Following this, five levels of resilience of urban mobility are generated, high, medium-high, medium, low-medium and low.

Table 63: Description of Resilience Levels for each Stage of Analysis, Persistence, Adaptability and Transformability

Levels	Description	Codified Result
High	No group with average of resilience lower than 5	10
Medium-High	1 of the groups with average of resilience lower than 5	7.5
Medium	2 of the groups with average of resilience lower than 5	5
Low-Medium	3 of the groups with average of resilience lower than 5	2.5
Low	4 of the groups with average of resilience lower than 5	0

This section addresses the final analysis in the two case scenarios, best and worst. The difference is established by the quantitative approach, in order of the income parameters considered. The income parameters have a lower and higher salary, generating best- and worst-case scenarios. Mixing these different scenarios of the quantitative approach with the qualitative, different levels of resilience of urban mobility may be generated. At the end of each section, there is the final resilience of urban mobility, considering the best- and worst-case scenario. The results are based on equation 15, using the codified results in Table 64. This process to generate results is applied to the best- and worst-case scenarios.

$$Final\ Resilience\ of\ Urban\ Mobility\ (FRUM) = \frac{Persistance + Adaptability\ (H2) + Adaptability\ (H3) + Adaptability\ (H4) + Transformability}{50} \quad (15)$$

Table 64: Final Resilience of Urban Mobility (FRUM) – Description of possible results based on Equation 15

Resilience Level	Description
High	1 $\leq$ FRUM < 0.75
Medium-High	0.75 $\leq$ FRUM < 0.5
Medium	FRUM = 0.5
Low-Medium	0.5 < FRUM < 0.25
Low	0.25 $\leq$ FRUM < 0.0

8.5.1. Best-Case Scenario

This section addresses the resilience of urban mobility of Rio de Janeiro under the best-case scenario. The order of analysis first focusses on persistence, then adaptability, and lastly transformability.

Figure 92, Figure 93 and Figure 94 shows the summarised results from all analyses of the persistence stage of the resilience of urban mobility. The first one presents the scale of results generated from the interpretation of the qualitative and quantitative approach. The second figure is the calculation of the average considering all data from each group of analysis. The third figure is the map representation of the result, based on Figure 93, following the rule of Table 63.

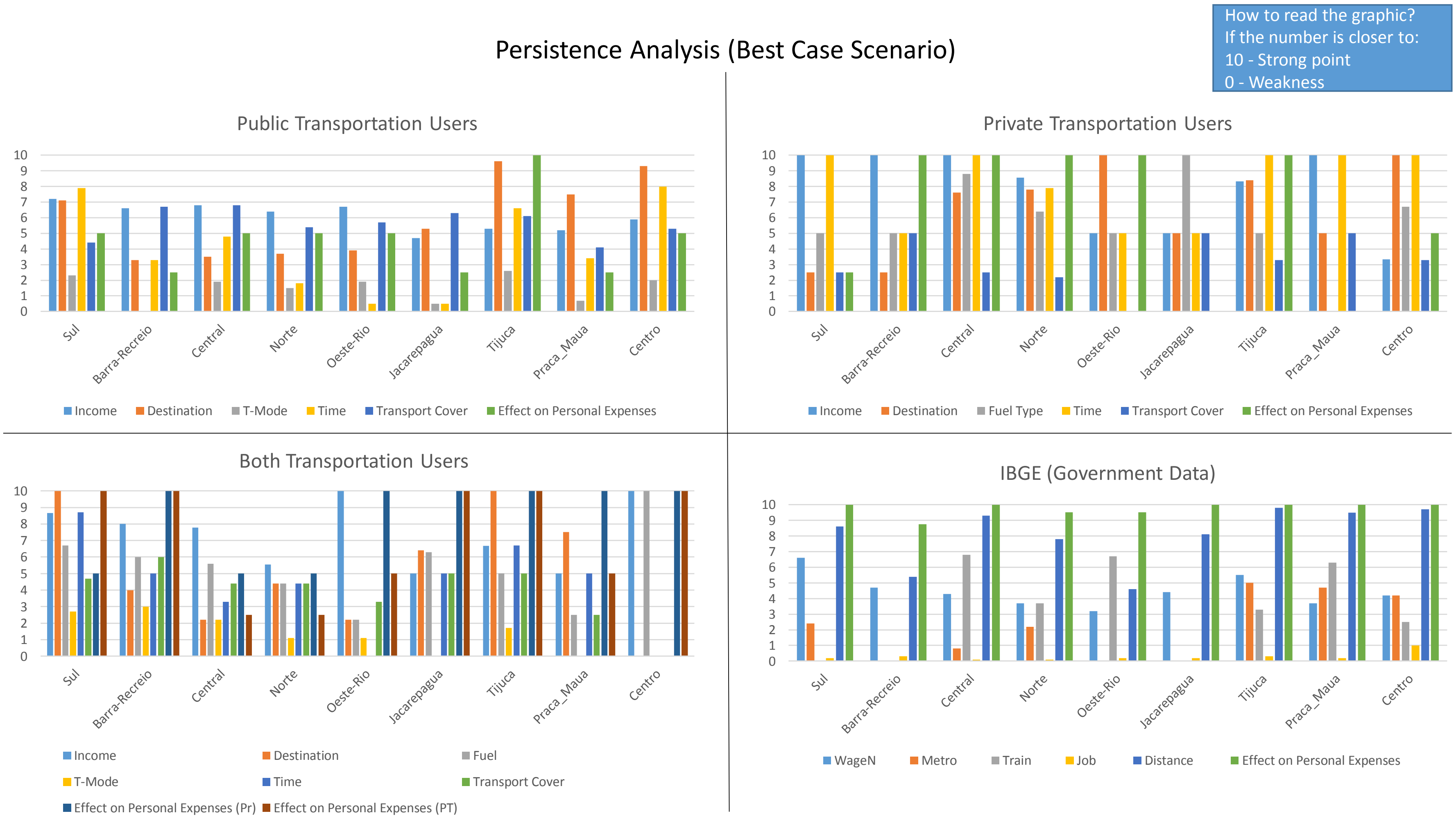


Figure 92: Persistence Scaled Values for each Variable for each Group of Analysis

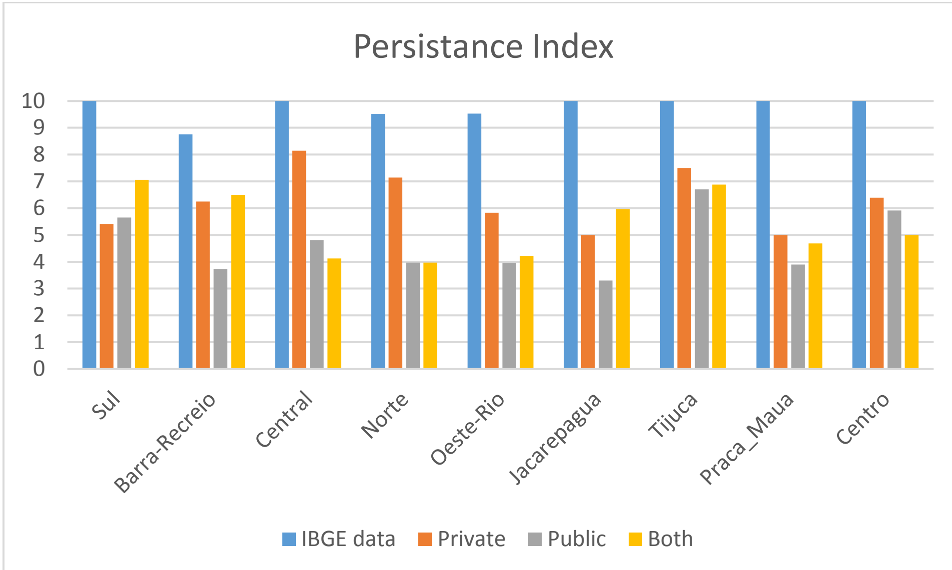


Figure 93: Persistence Index under the Best-Case Scenario

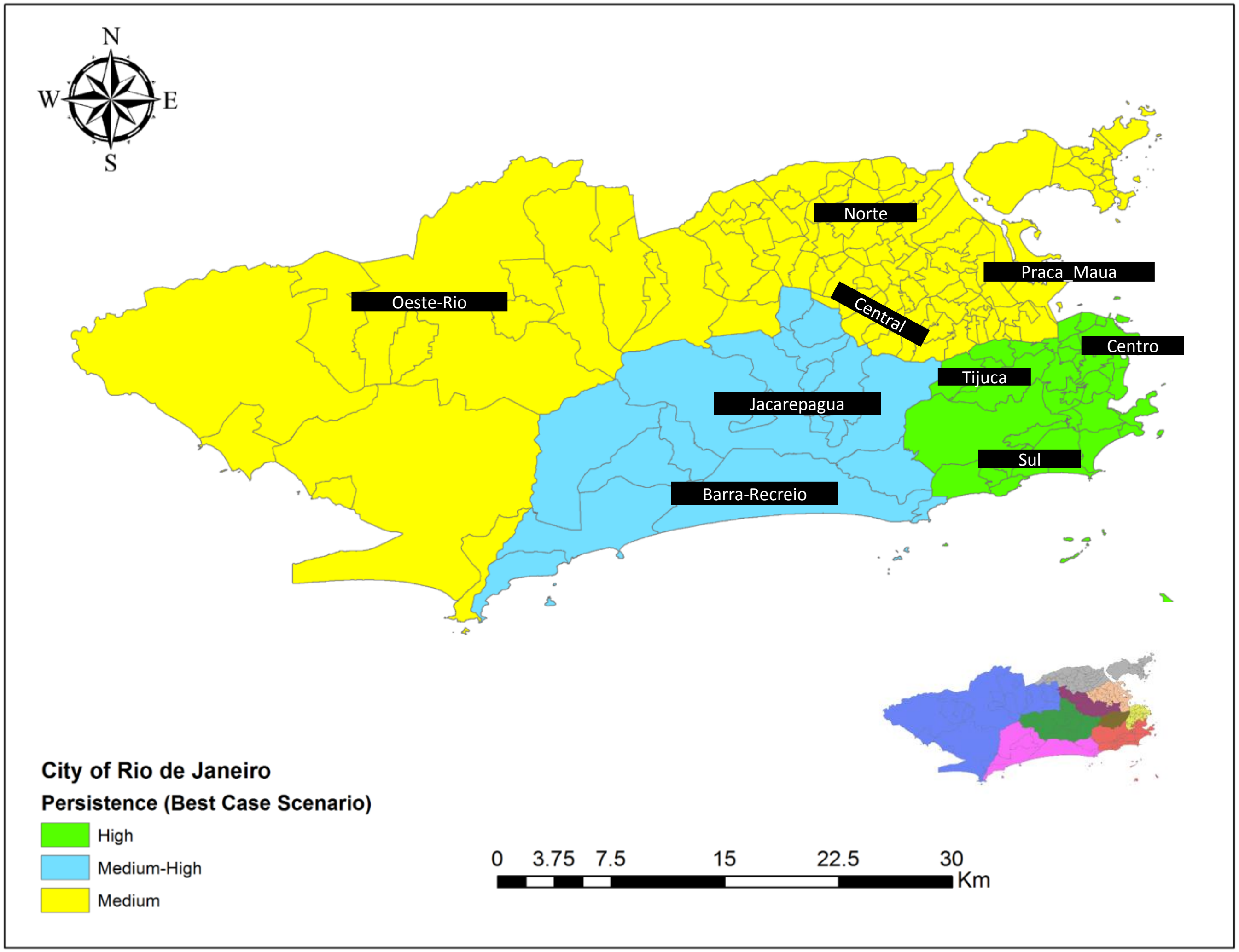


Figure 94: Persistence Index in a Map – Best-Case Scenario

In Figure 94, it is observed that macrozones Centro, Sul and Tijuca present high persistence levels, which means that residents from these macrozones possibly maintain a mobility pattern and conditions that does not directly jeopardise their social conditions. Even though there are weakness in these macrozones, there are strong points that support overcoming the situation, such as higher income level, destination of work near residence, travel time, high use of alcohol as fuel for private transportation users and low effect of transportation costs on personal expenses.

Macrozones Barra-Recreio and Jacarepagua presented a medium-high level of persistence, because of public transportation users. This group of analysis, in the case of Barra-Recreio residents, presented long trips to work in terms of distance and time, high effect of transportation costs on personal expenses and higher use of bus or BRT system to reach work, plus the need to use metro combined, which makes the transportation cost higher. In the case of Jacarepagua, the public transportation users present weaknesses in the income level, higher use of bus or BRT system (low level of T-mode) and an effect of transportation cost on personal expenses.

Macrozones Oeste-Rio, Central, Norte and Praca_Maua presented medium level of persistence, because of public and both transportation users. In macrozone Oeste-Rio the weakness for these focus groups are destination far from residence, higher use of bus or BRT systems, travel time, and transportation cover, which is whether the contractor paying enough to cover monthly transportation costs. For residents of macrozone Central, the weaknesses are almost the same from Oeste-Rio, plus the effect of transportation costs on personal expenses. For the residents of macrozone Norte, the weaknesses are destination of work, high use on bus or BRT system, travel time and high use of gasoline as fuel type by both transportation user. Macrozone Praca_Maua presented weaknesses in income level, high use of bus or BRT systems, effect of transport costs on personal expenses and fuel type chosen by both transportation users.

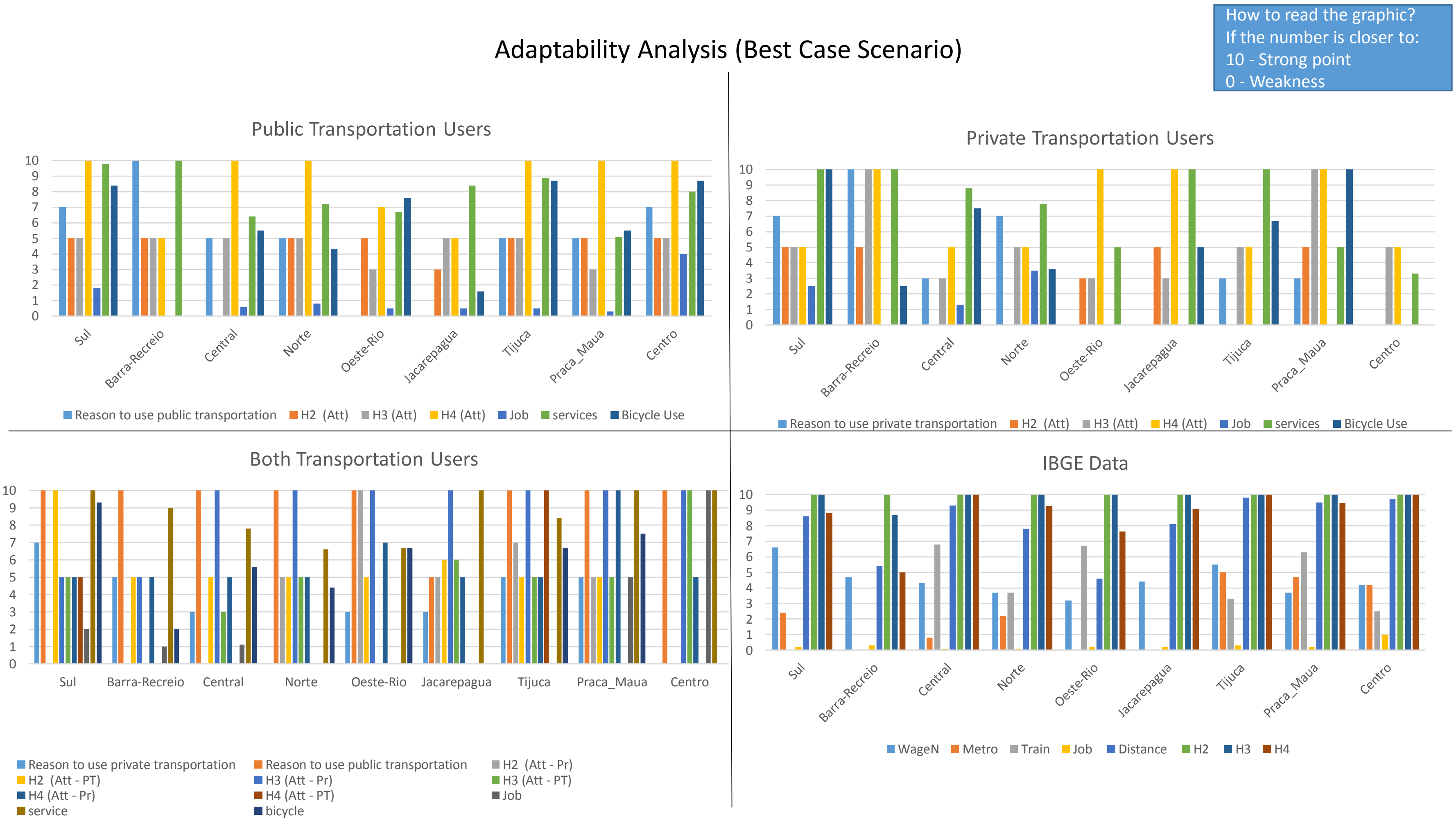


Figure 95: Adaptability Analysis – Levels of Contribution of each Variable based on interpretation of quantitative and qualitative data – Best-Case Scenario

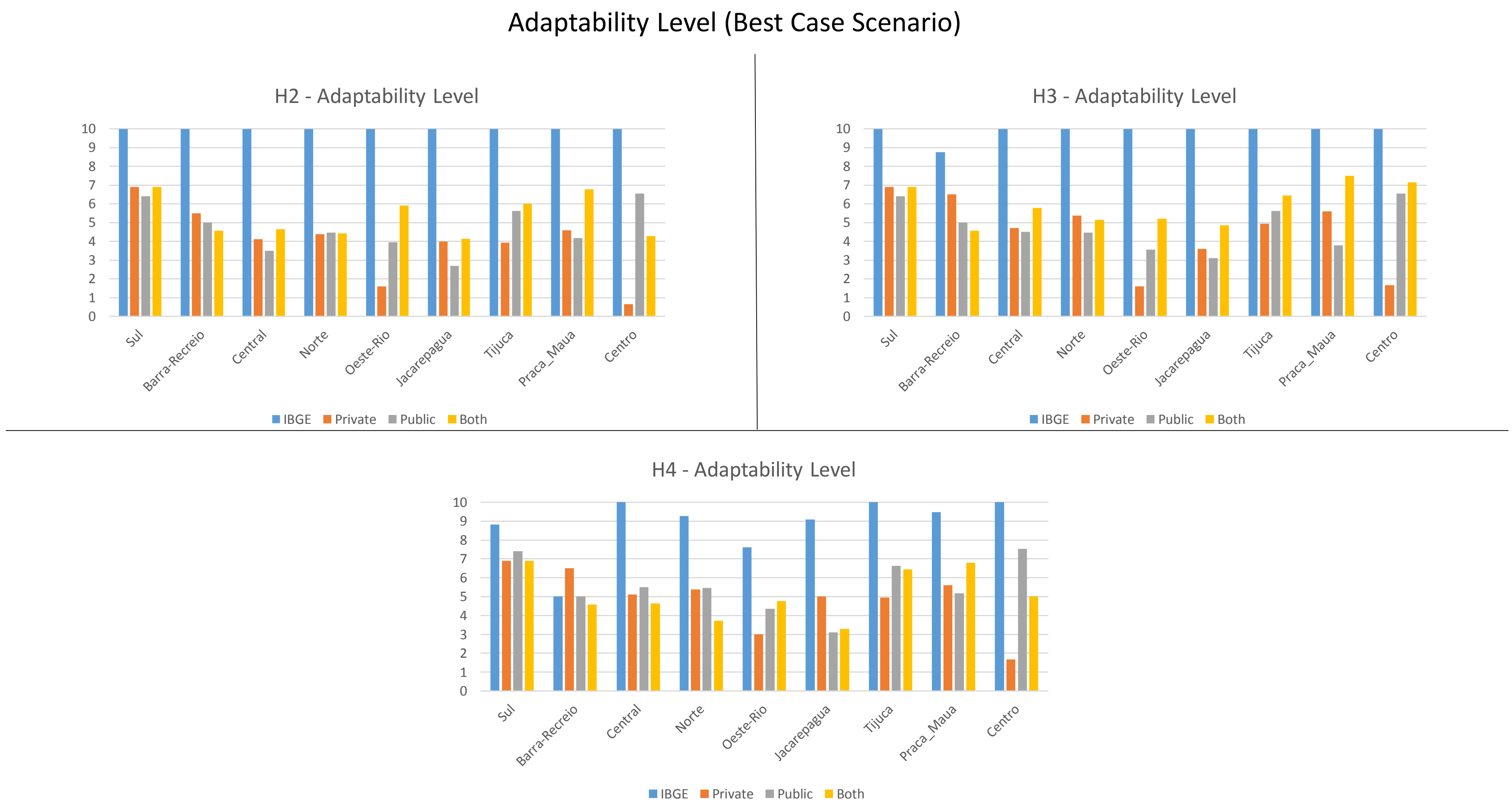


Figure 96: Adaptability level for the each group of analysis and each threat case (H2, H3 and H4)

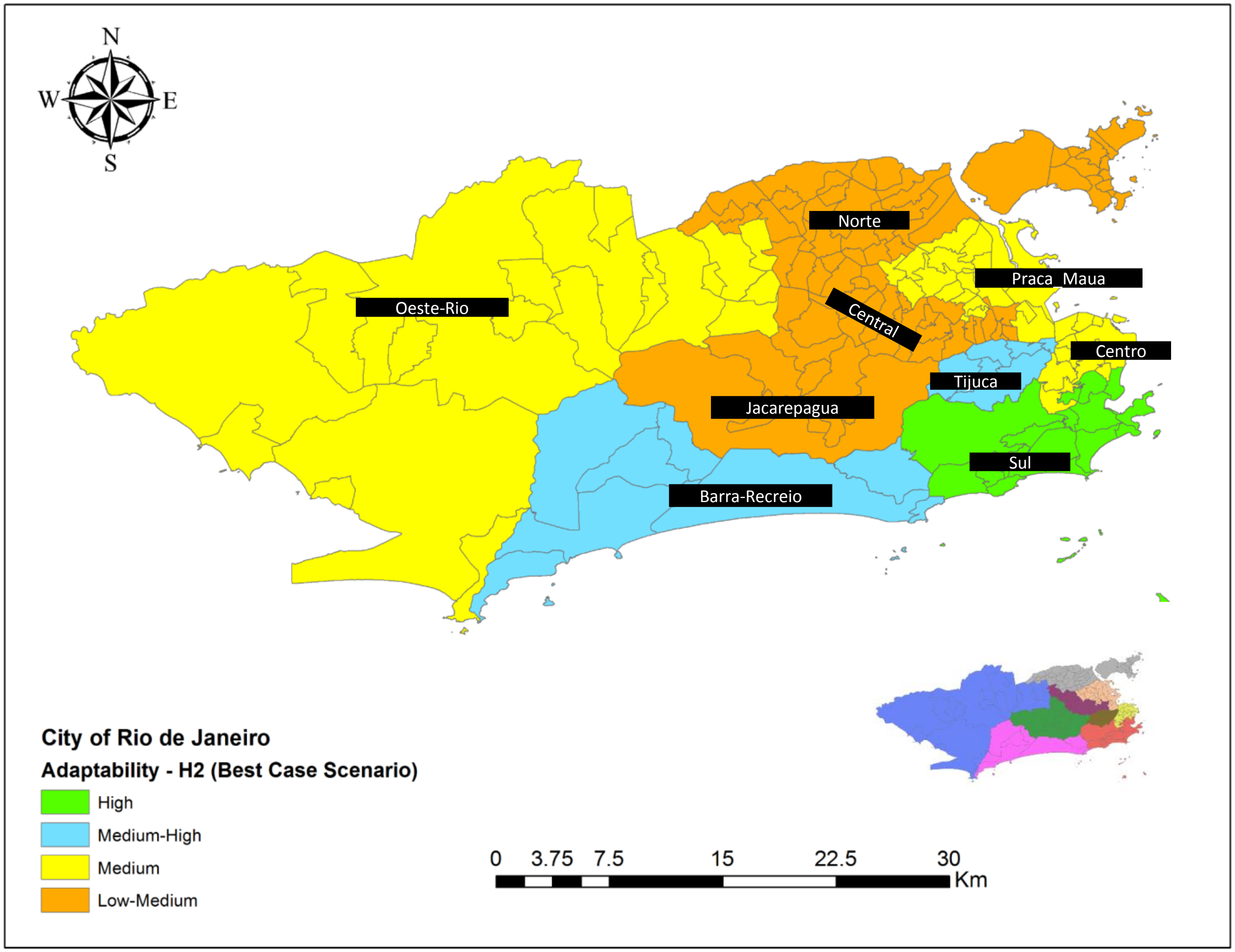


Figure 97: Adaptability level for the H2 threat – Best-Case Scenario

Figure 97 presents the results of the level of adaptability face to the H2 threat, considering the data from Figure 95 and Figure 96. The macrozone with high adaptability level is Sul, because from all groups of analysis (Figure 96 – H2 adaptability level), none presented less than 5 in the average calculation.

The macrozones with the medium-high level of adaptability are Barra-Recreio and Tijuca, because one of the focus groups for each of these macrozones presented adaptability level lower than 5. In the case of Barra-Recreio, it was both transportation users, because of the attitude towards H2 scenario case, mostly the sample of this macrozone would continue to use the private transportation (fossil fuel-based) or bus/BRT as modal choices. Furthermore, both transportation users find it difficult to find a job in the same or neighbourhood district and most of respondents believe it is not possible to cycle to work.

Macrozone Tijuca presented weakness on the group of private transportation users. Specifically, the weakness of this group is related to the reason why they use public transportation, in other words, because it is the only option and respondents are not satisfied with public transportation. Furthermore, regarding the attitude towards H2 threat level, some would feel financially affected and would continue to use buses or BRT systems. Another weakness is the difficulty of finding a job in the same or neighbourhood district.

The macrozones with medium level of resilience are Oeste-Rio, Praca_Maua and Centro. Macrozones Oeste-Rio and Praca_Maua present weaknesses on the public and private transportation users. Macrozone Centro presented weaknesses on the private and both transportation users.

In the case of macrozone Oeste-Rio, the weakness point of public transportation users are related to low satisfaction with the public transportation system, pointing out that it is the only option for the respondents, and there is difficulty of finding a job in the same or neighbourhood district of residence. Furthermore, in relation to the attitude, a significant part of sample replied that they would continue to use bus or BRT systems in case there is an increase of price, even if it affects personal expenses. Private transportation users of this macrozone, also presents weakness on the reason to use private transportation, related to dissatisfaction with public transportation. Furthermore, the attitude towards the H2 threat level is related to continue to use private transportation. Besides these weaknesses of private transportation users, respondents find it difficult to find jobs and services in the same or neighbourhood district from where they live.

In macrozone Praca_Maua, the public transportation users presented problems related to the reason why using public transportation, which is related to a lack of option because of the income levels, in other words, respondents are not satisfied with the public transportation system, however there is no other option. The attitude towards the H2 threat level, for this group, is also a weakness, because at least half of the sample would continue using buses or BRT systems. Besides these factors, there is difficulty in finding jobs and services in this macrozone. In relation to the private transportation users, they would continue using private transportation, as they are dissatisfied with public transportation. Besides these factors, they believe that it is not easy to find jobs or services in the same or neighbourhood district.

In macrozone Centro, the weak points of private transportation are related to the dissatisfaction with public transportation and continuity of use of private transportation in the H2 threat scenario. Furthermore, these users believe that it is not easy to find jobs or services in the same or neighbourhood district and that it is not possible to use the bicycle to reach a train or metro station. In relation to both transportation users, some would continue to use private transportation, others would continue to use bus, and majority believe that it is hard to find a job in the same or neighbourhood district.

The macrozones with low-medium adaptability level are Jacarepagua, Central and Norte. These three macrozones have weak groups, private, public and both transportation users. In the case of macrozone Jacarepagua, in all three groups, there is a dissatisfaction with public transportation, leading to the continuity of bus or BRT use or private transportation use. Besides this, all three groups (private, public and both transportation users) believe it is not easy to find a job in the same or neighbourhood district and that it is not possible to reach a train or metro station by bicycle.

In macrozone Central, in general, there is a higher dissatisfaction with public transportation. However, for some, it is the only option, as most would continue to use bus or BRT system and private transportation users would tend to continue their mobility pattern. Furthermore, amongst all respondents of this macrozone, most believe that it is difficult to find a job in the same or neighbourhood district. Macrozone Norte presents a similar logic from Central, with one additional weakness that most respondents agree that it is not possible to reach a train or metro station on a bicycle.

For the next threat levels, what can change the levels of adaptability are the quantitative approach and the attitude faced with each threat level of the qualitative data. For this reason, the focus on the analysis of adaptability faced with H3 and H4 threat levels are on the attitude of the qualitative data and H2, H3 and H4 data on the quantitative approach. Figure 97, Figure 98 and Figure 99 are based on Figure 95 and Figure 96.

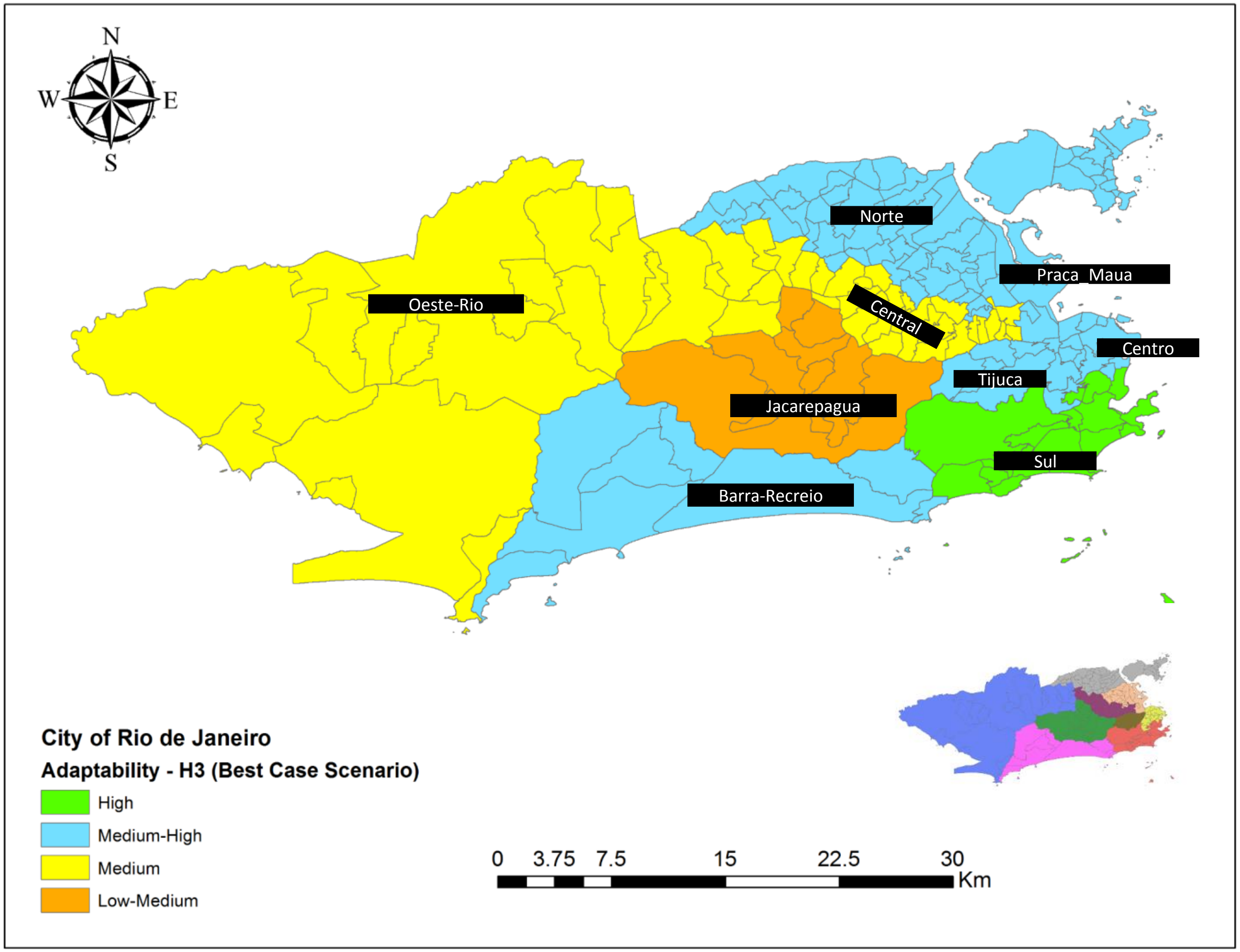


Figure 98: Adaptability level for the H3 threat – Best-Case Scenario

Considering the best-case scenario, Figure 98 presents the adaptability level for the H3 threat. Macrozone Sul maintained itself on the high level of adaptability. Macrozones Barra-Recreio and Tijuca maintained the medium-high level of adaptability.

Macrozones Praca_Maua increased the adaptability level from medium to medium-high, because private transportation users, at this threat level, presented higher possibility to shift to public transportation. Macrozone Norte increased the adaptability level from low-medium to medium-high, because private and both transportation users would shift the fuel type to alcohol.

Macrozone Central increased the adaptability level from low-medium to medium because of both transportation users, where some would shift the modal choice to metro and train system. Macrozone Oeste-Rio maintained the medium level of adaptability.

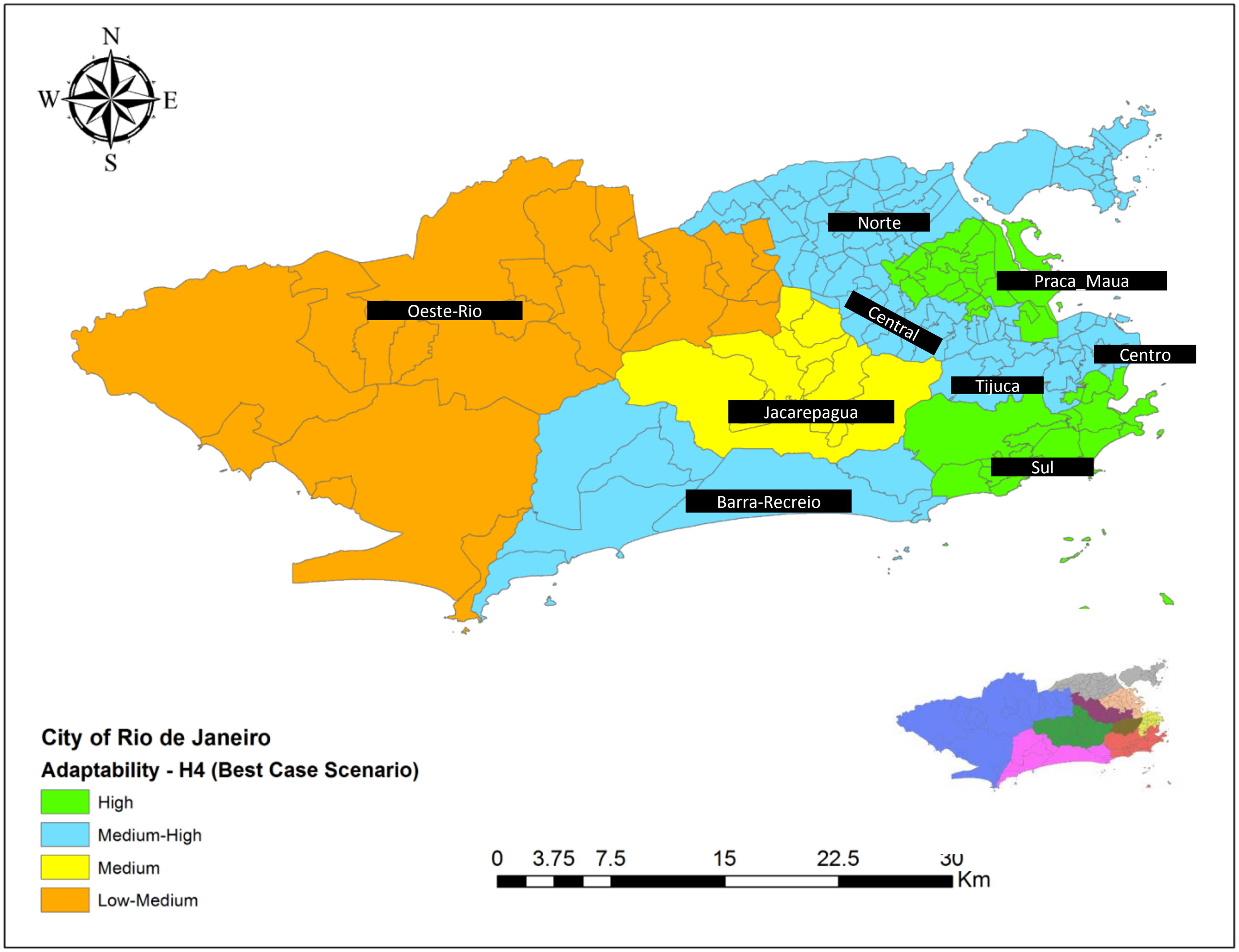


Figure 99: Adaptability level for the H4 threat – Best-Case Scenario

Considering the best-case scenario, Figure 99 presents the adaptability level for a H4 threat. Macrozone Sul maintains a high level of adaptability. Macrozone Praca_Maua increased the adaptability level from medium-high to high, because there is a higher shift of the private, public and both transportation users to metro and train system.

Macrozones Barra-Recreio, Centro and Norte maintain a medium-high level of adaptability. Macrozone Central increased the level of adaptability from medium to medium-high, because there is higher shift of private transportation users to using alcohol as fuel and public transportation users to use metro or train as modal choices to reach work.

Macrozone Oeste-Rio is the only macrozone that reduces the level of adaptability from H2 to H4. It reduces it from medium to low-medium because both transportation users affirm that they would sacrifice personal activities (social and economic) to continue to go to work. Furthermore, the shift to alcohol as fuel or metro or train as modal choices is not significant.

Transformability Analysis (Best Case Scenario)

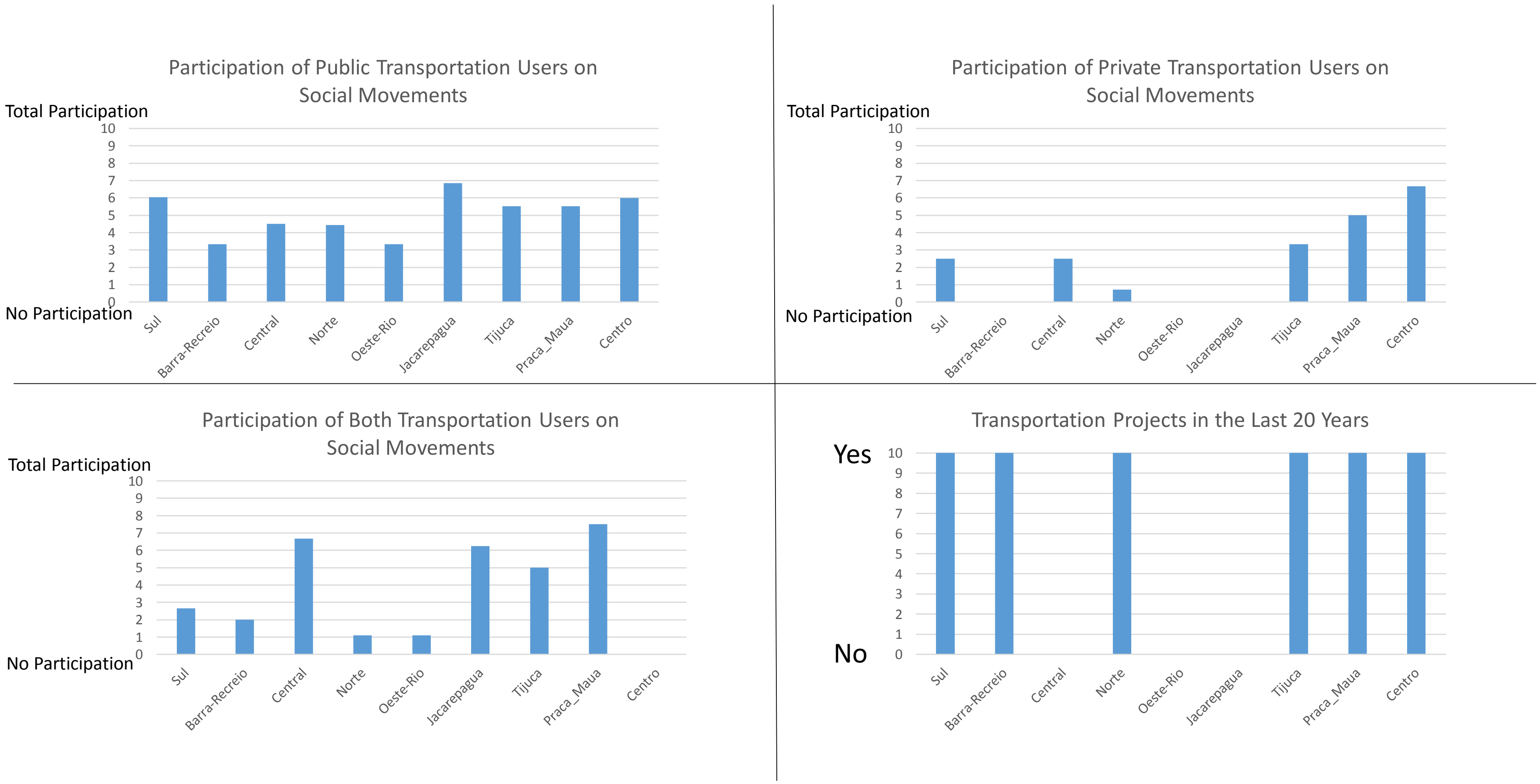


Figure 100: Transformability analysis based on participation on social movements by groups and implementation of electric transportation projects in the last 20 years

The analysis of the transformability stage of the resilience of urban mobility is based on Figure 100, Figure 101 and Figure 102. The first figure presents two types of variables, first, the level of participation of public, private and both transportation users on social movements. Second is whether the macrozone has received electric mobility projects in the last 20 years.

Figure 101 presents the level of transformability based on the information in Figure 100. Figure 102 presents the result represented in a map, based on the rule of Table 63, using data from Figure 100 and Figure 101. Furthermore, the transformability level is the only stage of analysis that does not have a best- or worse-case scenario. Therefore, this analysis serves both scenarios.

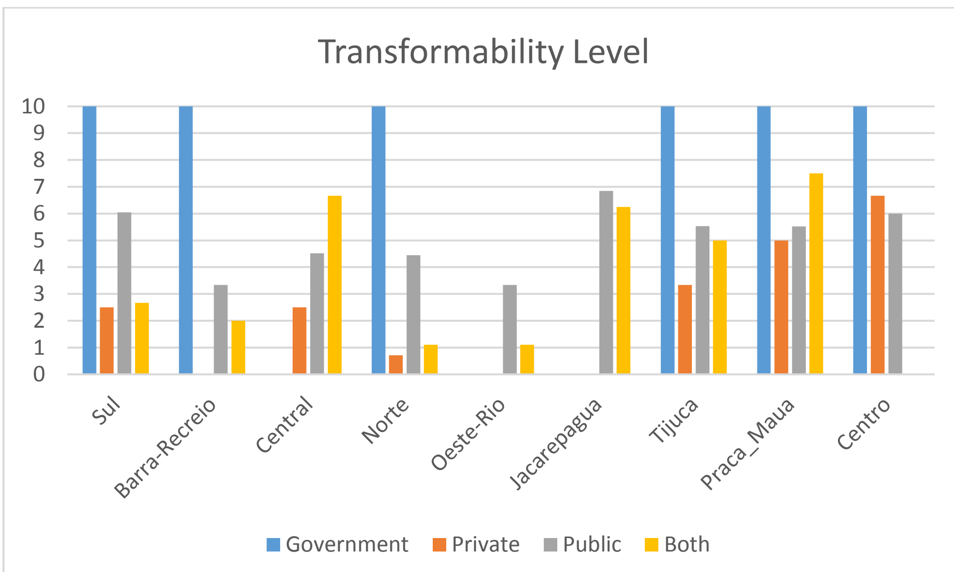


Figure 101: Transformability Level of the City of Rio de Janeiro by Macrozone and Group of Analysis

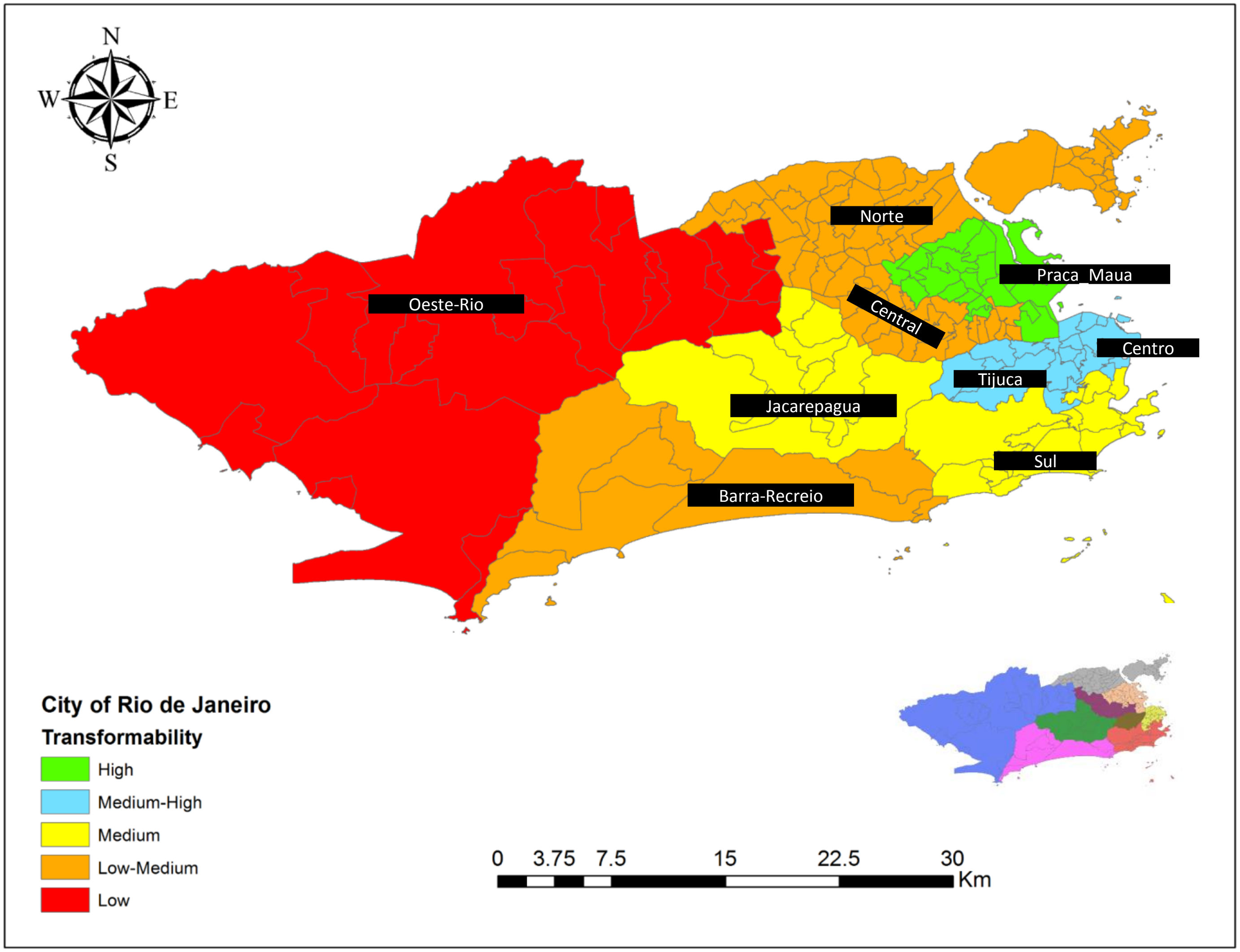


Figure 102: Transformability Level based on Figure 100 and Figure 102

In Figure 102, macrozone Praca_Maua presents a high level of transformability, because 50% or higher percentage of the sample of the three groups of analysis already participated in a social movement (e.g. protest) related to urban mobility. Furthermore, this macrozone received electric mobility projects.

Macrozone Centro and Tijuca present a medium-high level of transformability. In the case of macrozone Centro, it is because of both transportation users, in which none of respondents participated in a social movement to improve urban mobility. Macrozone Tijuca presents a low participation of private transportation users on social movements.

Macrozones Jacarepagua and Sul present a medium level of transformability. In the case of Jacarepagua, this level is because of two reasons. Firstly, private transportation users do not participate in social movements that address the improvement of urban mobility and secondly, no electric public transportation implemented in this macrozone in the last 20 years. In macrozone Sul, the medium level of transformability is explained by the low participation of private and both transportation users on social movements related to improvement of urban mobility.

Macrozones Barra-Recreio, Central and Norte present a low-medium level of transformability. In macrozone Barra-Recreio, the level of transformability is explained by the low participation of private, public and both transportation users in social movements related to the improvement of urban mobility. Macrozone Central presents lack of electric transportation projects in the last 20 years and low participation of private and public transportation users on social movements. In the case of macrozone Norte, there is a low participation of private, public and both transportation users on social movements.

Macrozone Oeste-Rio presents a low level of adaptability, because there has been no electric transportation project in the last 20 years and all groups of analysis present low participation in social movements related to improving the urban mobility.

Finally, this section addresses the result of the resilience of urban mobility, considering all results generated through this section. Figure 103 presents the levels of resilience of each stage of analysis of the resilience of urban mobility, considering the best-case scenario. Figure 104 presents the results considering equation 15, Table 63, Table 64 and Figure 103.

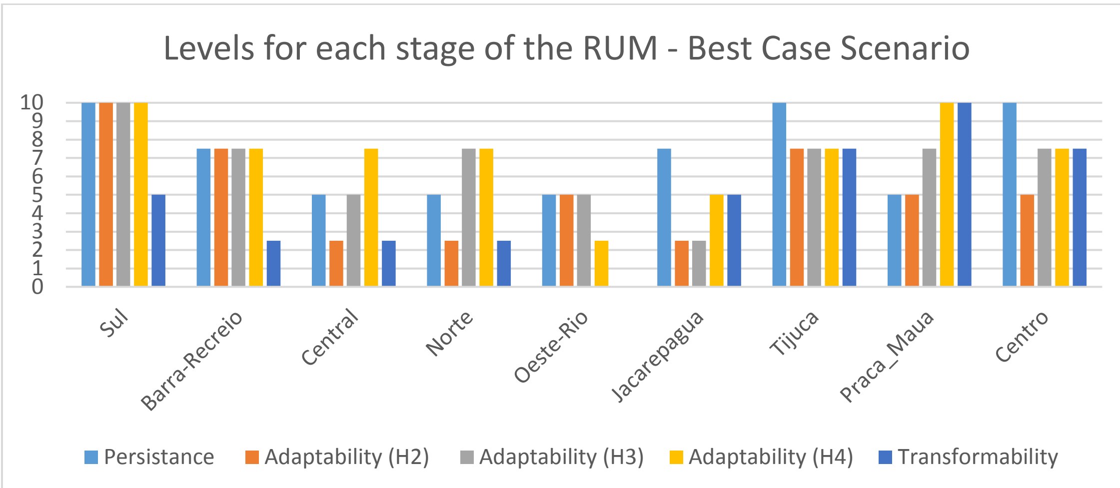


Figure 103: Levels of each stage of the resilience of urban mobility (RUM) – Best-Case Scenario

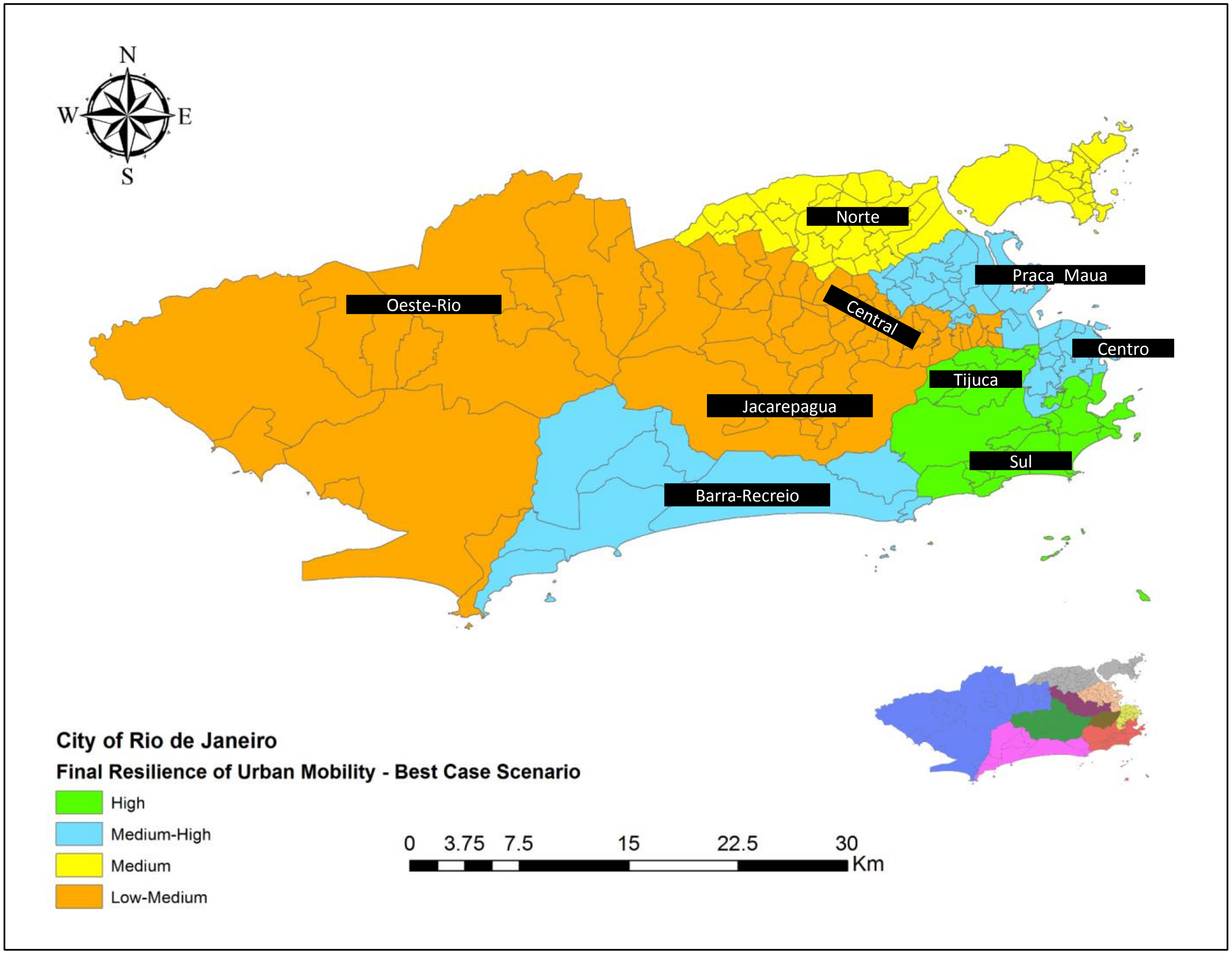


Figure 104: Final Resilience of Urban Mobility of the City of Rio de Janeiro – Best-Case Scenario

Figure 104 shows that macrozones Sul and Tijuca have high levels of resilience of urban mobility. Macrozones Barra-Recreio, Centro and Praca_Maua presented a medium-high level of resilience. In the case of Barra-Recreio, the transformability is the weakness of this macrozone, because of low participation of residents on social movements.

In Praca_Maua, the medium-high level of resilience is explained by the resistance towards the choosing of electric transportation modes. There is a general dissatisfaction towards public transportation, leading to the shift in the use of train or metro systems when faced with the H3 threat level, and not the H2.

Macrozone Centro presents a high persistence level, which may mean a higher possibility to maintain the currents mobility patterns faced with fossil fuels. However, faced with the H2 threat level, there is a medium level of adaptability. This value improves at the H3 and H4 threat levels.

Macrozone Norte presents a medium level of resilience of urban mobility, with similar pattern as macrozone Praca_Maua, plus the low level of transformability, because of low participation of residents of this area in social movements.

Macrozones Jacarepagua, Central and Oeste-Rio present a low-medium level of resilience of urban mobility. In the case of Jacarepagua, this level of resilience is explained by the difficulty of accessibility to an electric mobility option, such as train or metro. At the H4 threat, the level of adaptability improves because of the shift to private transportation, using alcohol as fuel. Furthermore, there has been no electric transportation project in this macrozone in the last 20 years.

Macrozone Central presents low persistence, adaptability (H2 and H3) and transformability level. In this macrozone, residents are dissatisfied with public transportation and resist shifting to train or metro systems. Furthermore, this macrozone did not receive new electric transportation projects in the last 20 years and it has low participation of residents in social movements related to improving urban mobility. Macrozone Oeste-Rio presents problems in all stages of the resilience of urban mobility.

8.5.2. Worst-Case Scenario

This section addresses the resilience of urban mobility results of Rio de Janeiro, considering the worst-case scenario and following the same logic from the previous section. It is important to highlight that the quantitative approach is the only one that addressed the best- and worst-case scenarios. However, the joining of qualitative results with the worst-scenario of the quantitative approach may generate different resilience levels. The worst-case scenario of the quantitative approach is based on considering the lower income levels of the different parameters used in the quantitative approach. Therefore, this section directly presents the levels of persistence and adaptability, without presenting the variable, because they are the same as in the best-case scenario. The result of the resilience of urban mobility is driven by the quantitative approach, which is the focus of this section, because the other group of analysis and variable do not change. Furthermore, the transformability levels are the same for the worst-case scenario.

Persistence and Adaptability (H2, H3 and H4) Levels (Worst Case Scenario)

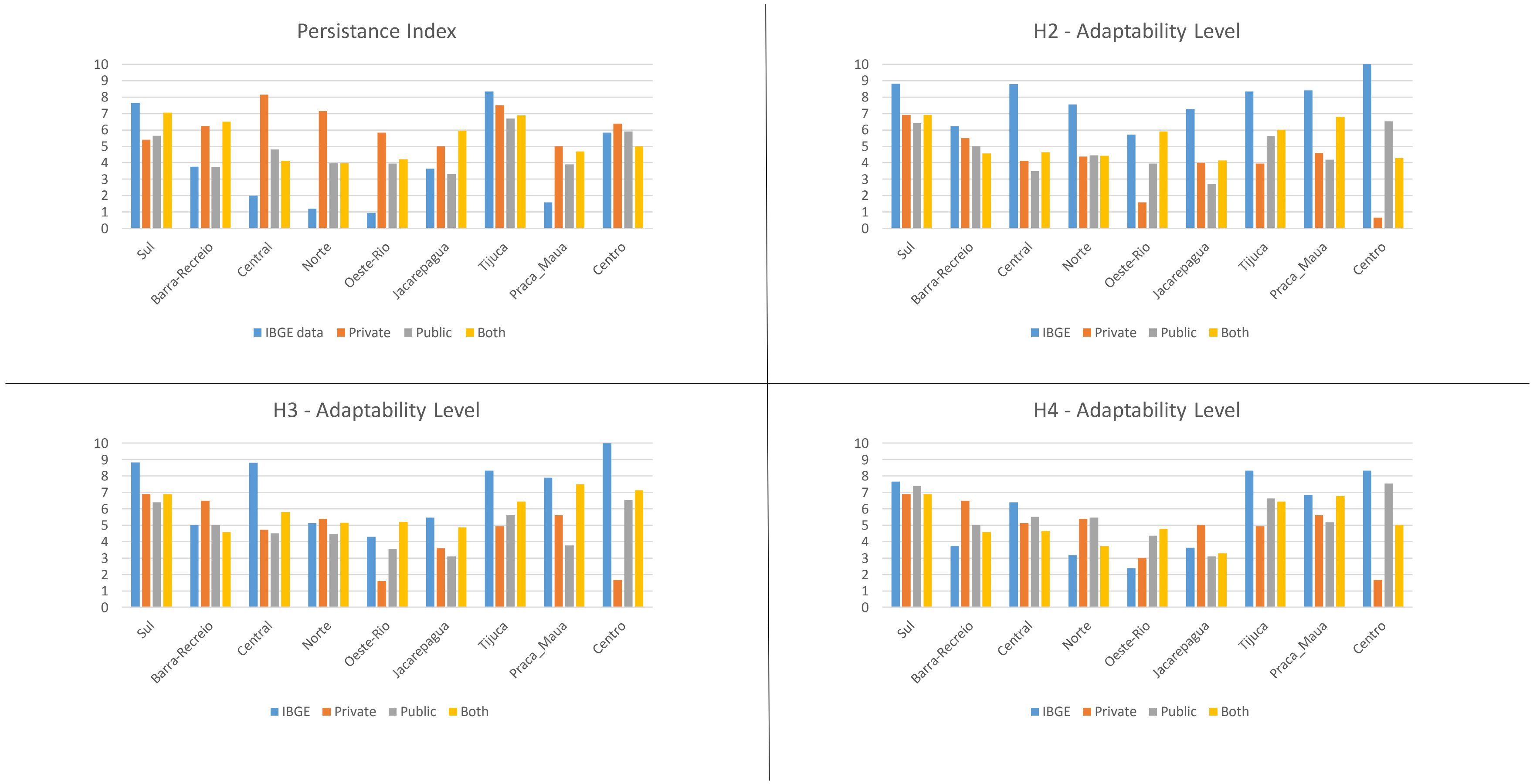


Figure 105: Levels of persistence and adaptability of each macrozone for each group of analysis – focussing on the worst-case scenario

Figure 105 presents the levels of persistence and adaptability of each macrozone and group of analysis. Figure 106, Figure 107, Figure 108 and Figure 109 show the result of the persistence level, based on Figure 105 and Table 64. To review the meaning of the results of the IBGE group of analysis, the level of effect of transportation on personal expenses represents that the residents of each macrozone may be living in current times (persistence) and under possible threats (H2, H3 and H4). At the persistence stage, it means the level of effect on costs with basic needs and superfluous costs (e.g. shopping or cultural activities) that residents of each macrozone may be living. At the adaptability level, it only considers the effect of transportation costs on basic needs costs.

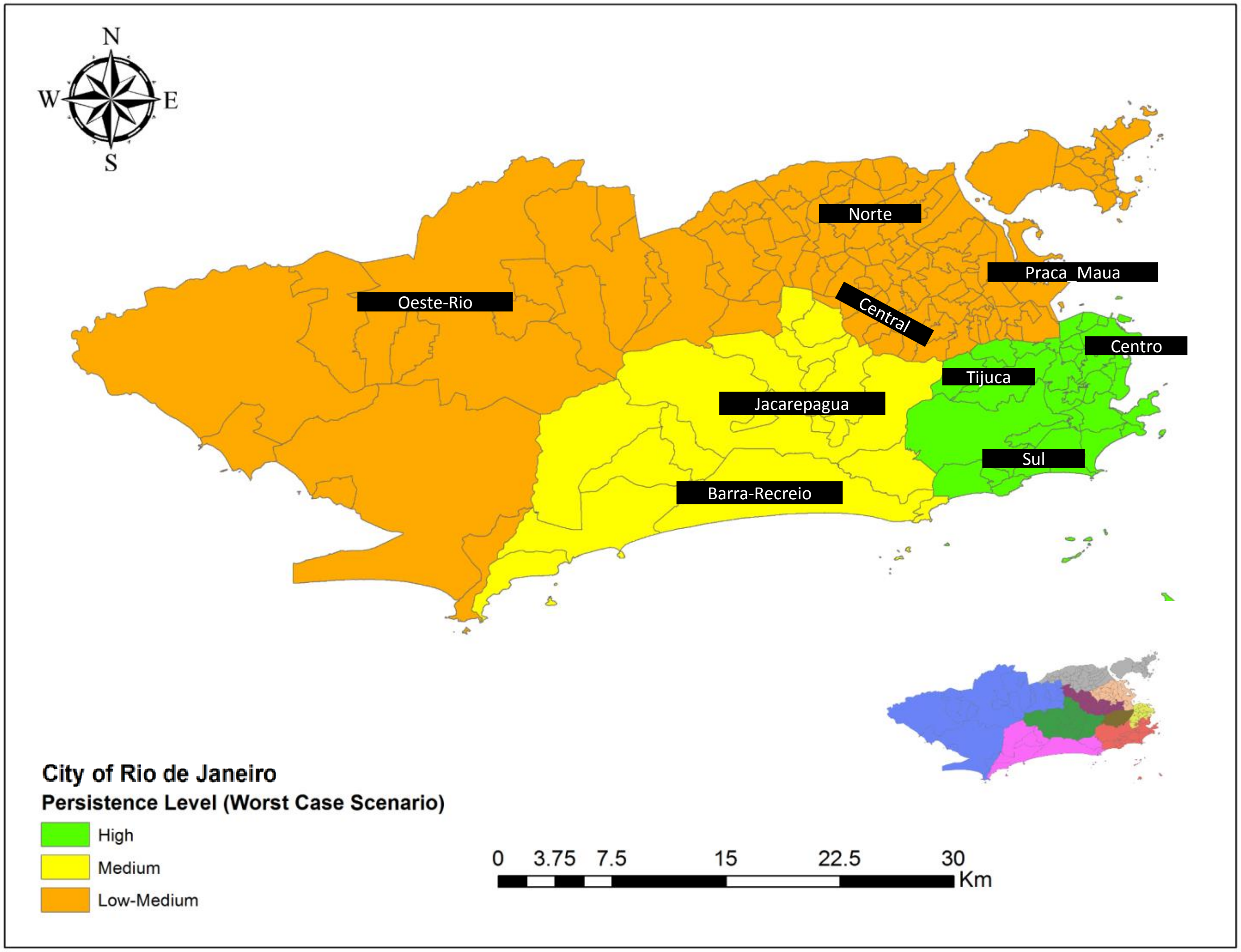


Figure 106: Persistence Level – Worst-Case Scenario

Figure 106 shows that macrozones Sul, Centro and Tijuca have a high level of persistence. Macrozones Barra-Recreio and Jacarepagua present a medium level of persistence, because of the high number of residents who earn until two minimum salaries per month, which lead the IBGE group of data to be at a lower level. In addition, these two macrozones have problems with the public transportation users, which were already presented in the best-case scenario analysis.

Macrozones Oeste-Rio, Central and Norte present a low-medium level of persistence. Besides the problems with the qualitative approach is already presented in the best-case scenario. In the worst-case scenario, the IBGE group of analysis presents a low value, meaning a significant number of residents in these macrozones are already sacrificing personal costs.

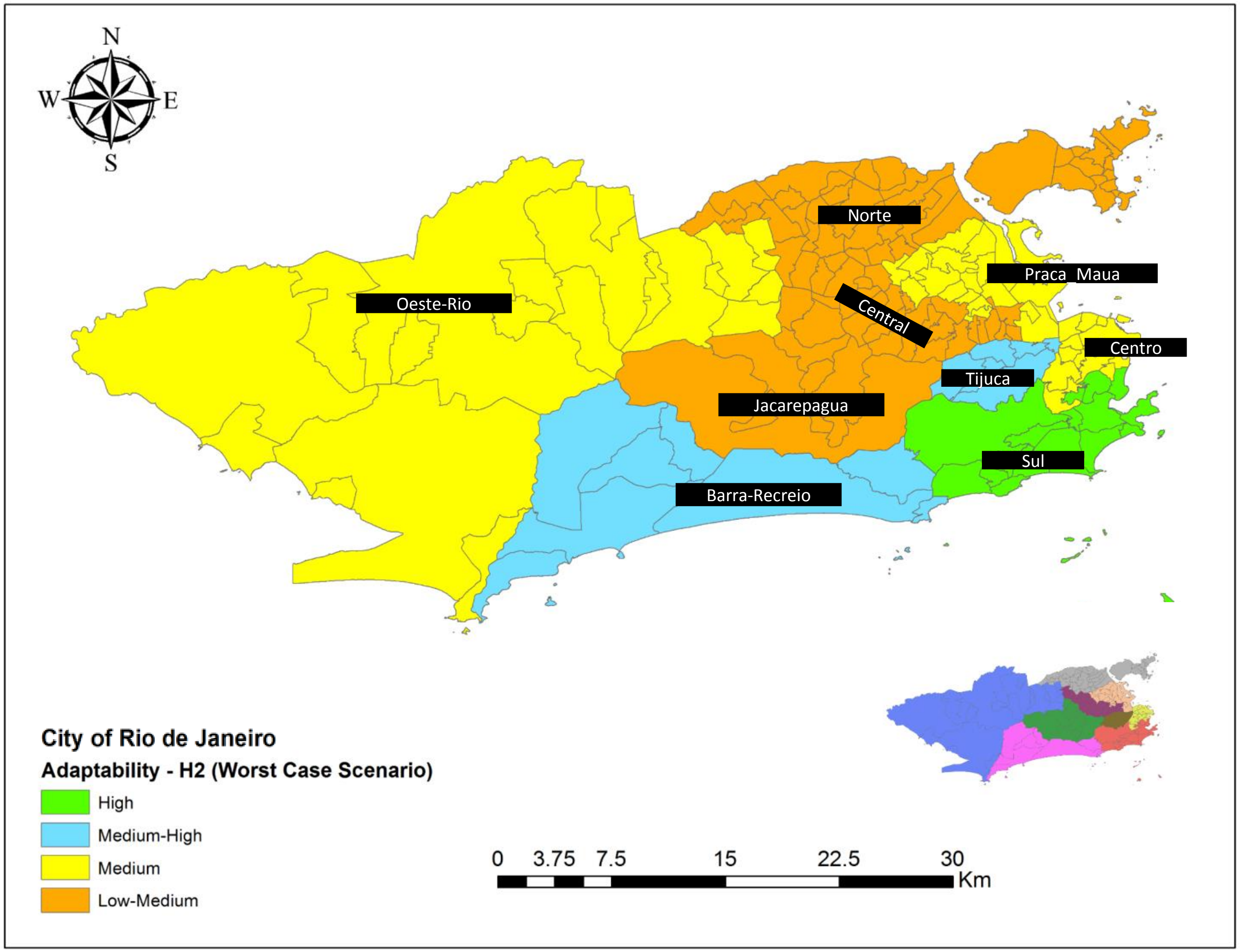


Figure 107: Adaptability level (H2) – Worst-Case Scenario

Figure 107 presents all macrozones with the same level of adaptability from the best-case scenario, when faced with a H2 threat level. There is a difference in the levels of adaptability of the IBGE group of analysis, however not at a significant level, which can reduce the adaptability level.

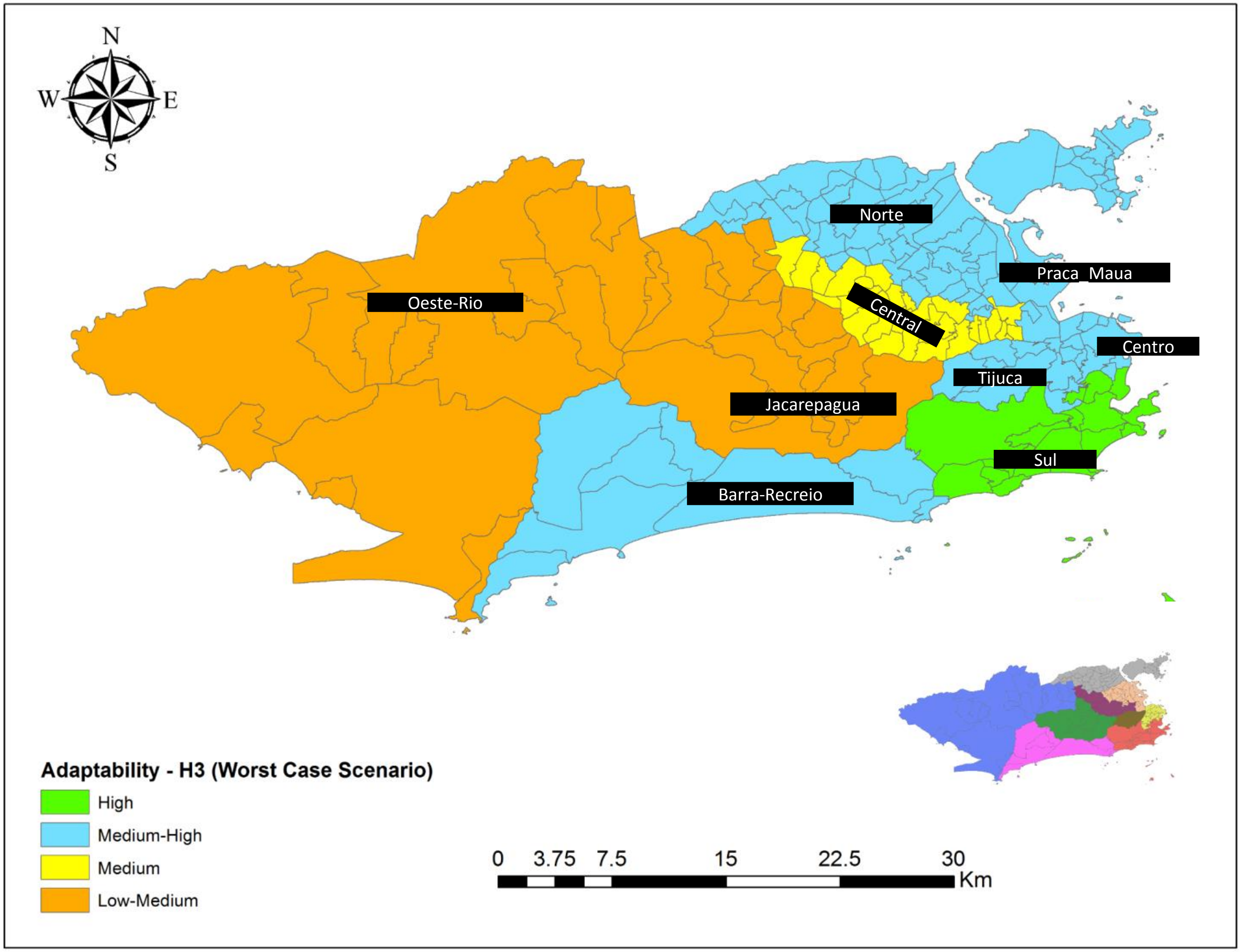


Figure 108: Adaptability level (H3) – Worst-Case Scenario

Figure 108, the only macrozone that presents a change of level in relation to the best-case scenario is Oeste-Rio, which presents a low-medium level of adaptability when faced with a H2 threat. This reduction in adaptability level in Oeste-Rio is explained by the high number of people living with less than two minimum salaries, which consequently results in a high effect of transportation costs in personal expenses, when considering the lower salaries of each wage parameter used in the quantitative approach.

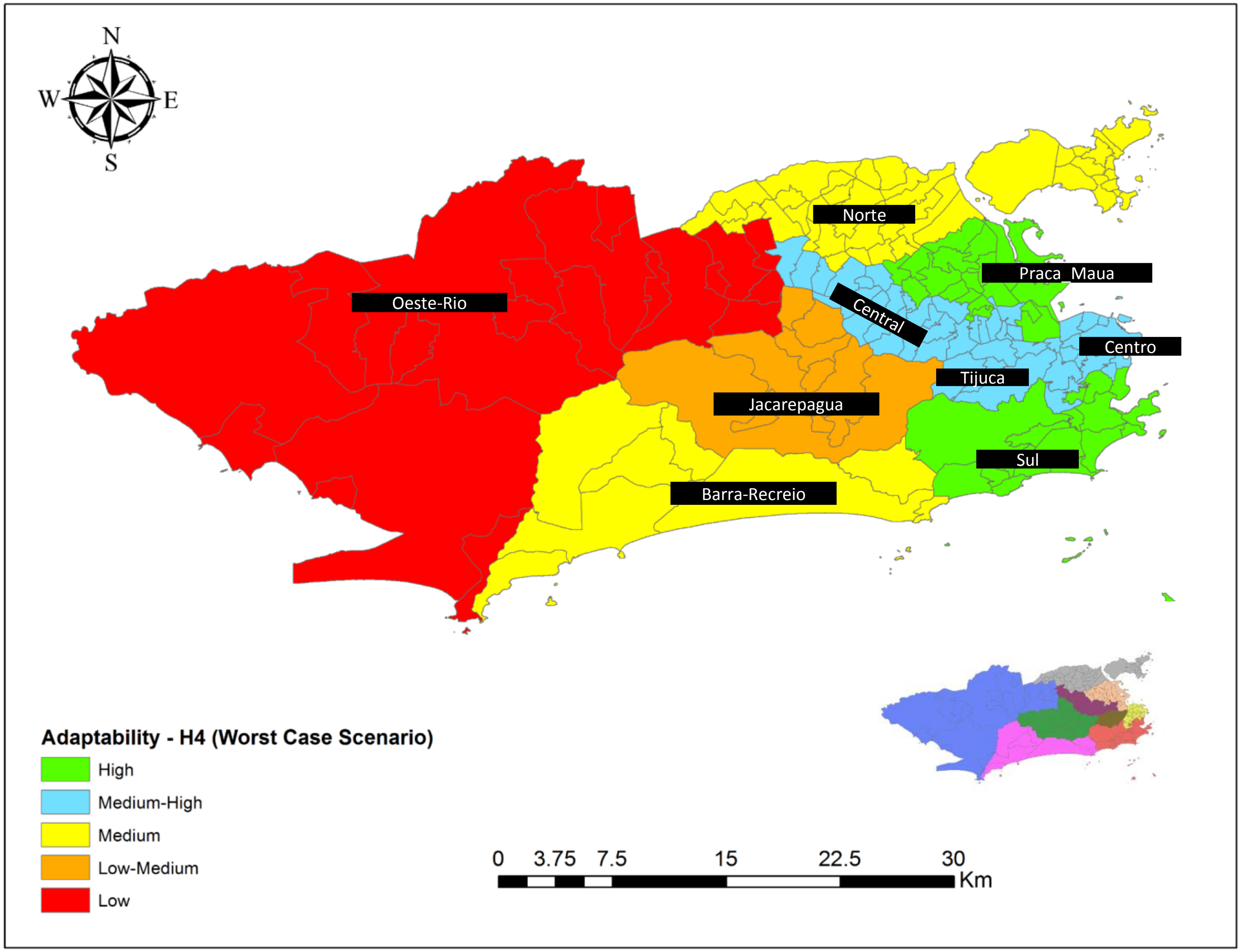


Figure 109: Adaptability level (H4) – Worst-Case Scenario

Figure 109 shows that macrozones Norte, Jacarepagua, Barra-Recreio and Oeste-Rio present lower level of adaptability (H4) in relation to the best-case scenario. The reason is that, for this level of threat (H4), these macrozones are highly vulnerable in order of the high number of residents with lower income.

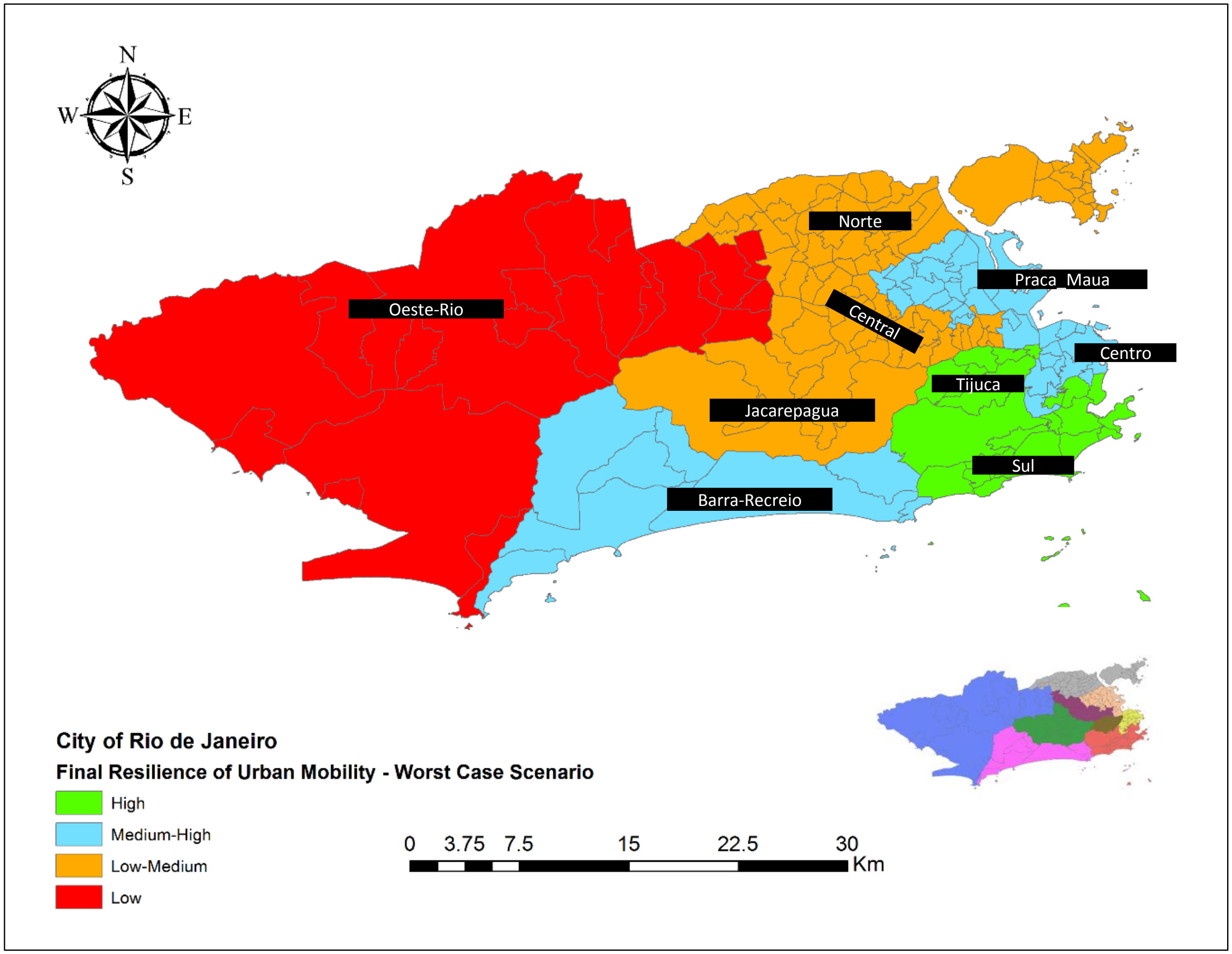


Figure 110: Final Resilience of Urban Mobility of the City of Rio de Janeiro – Worst-Case Scenario

The process to generate the result of the resilience of urban mobility, considering the worst-case scenario, follows the same logic from the best-case scenario. Furthermore, it considers the same transformability level from the best-case scenario. Figure 110 shows that macrozones Oeste-Rio and Norte are the ones that have different results from the final resilience of the best-case scenario. Macrozone Oeste-Rio reduces to a low level of resilience and Norte to a low-medium level of resilience of urban mobility.

CHAPTER 9

9. CONCLUSION AND REMARKS

This chapter presents the conclusions, seeking to point out the final view of the results and discusses whether the objectives of the thesis have been reached. Furthermore, this chapter outlines the limitations and further need for research.

9.1. Final Remarks about the Resilience of Urban Mobility of the City of Rio de Janeiro

This section focusses on the final remarks about the resilience of urban mobility of the city of Rio de Janeiro and addresses the elements that should be taken into consideration by planners, in order to increase the resilience of urban mobility when faced with fossil fuel threats.

Table 66, Table 67 and Table 68 present, respectively, the weaknesses of each macrozone of Rio de Janeiro based on persistence, adaptability and transformability elements. These final remarks are presented according to the perspective of the author of this thesis, based on the analyses presented in CHAPTER 8. Furthermore, Figure 111 offers the final remarks of the weak points of the persistence, adaptability and transformability stage of analysis from a geographical context of the city.

Firstly, it is possible to observe that the combination of problems (weaknesses) in each macrozone is different. This fact is a reflection of the different spatial and social characteristics, which each macrozone presents. There are changes, which the private and public sector can encourage to improve regarding the resilience of urban mobility. These changes can be more effective by understanding the spatial and social differences and consequently, the elements that need to be improved in each part of the city.

Table 66 shows that all macrozones have transportation problem, specifically public transportation. Although there are areas with more accessibility to metro or train stations, in all parts of the city there is a major use of the conventional bus system. What differentiates the macrozone, regarding transportation modes, is the way residents of each area combines the transportation modes. Depending on the combination, the prices can vary, as shown in Table 65.

It is possible to observe that in 2015, whose base price is used in this thesis, the use of train is 6% cheaper than bus or bus+bus, while metro is 9% more expensive, bus+metro is 46%, bus+train is 38% and train+metro is 74% more expensive. With the current price in 2016, these differences get worse in relation to bus+metro and bus+train. Considering that, it was observed that the mixture of transportation modes is a dominant pattern in the macrozone, which already has metro and train stations. This leads to a pattern of high expenses with transportation to reach the destination faster, or is dependent on the bus system, which is cheaper but leads to longer trips.

Furthermore, comparing the 2015 and 2016 prices, it is possible to observe that in approximately one year, the bus price will increase by 12%, train by 16%, metro by 11%, bus+metro by 41%, bus+train by 40% and train+metro by 10%. Regarding the fuel price, gasoline will increase by 13% and alcohol by 22%. The option of fuel, which could reduce the dependency on fossil fuel for the urban mobility, in this case alcohol, increased the price more than gasoline. This shows that there may not be an interest of the private or public sector to encourage the use of alcohol or electric-based public transportation.

Table 65: Transportation modes and fuel prices in the city of Rio de Janeiro – 2015 and 2016 (Brazilian Currency – R$)

Transportation Modes and fuels	2015 Price (R$)	Comparison with bus price (2015)	2016 price (R$)	Comparison with bus price (2016)	2015-2016 comparison ((2016/2015)-1)
Bus	3.4	0%	3.8	0%	12%
Train	3.2	-6%	3.7	-3%	16%
Metro	3.7	9%	4.1	8%	11%
Bus+Bus	3.4	0%	3.8	0%	12%
Bus+Metro	4.95	46%	7.0	84%	41%
Bus+Train	4.7	38%	6.6	74%	40%
Train+Metro	5.9	74%	6.5	71%	10%
Gasoline (R$/Litre)	3.2	-	3.6	-	13%
Alcohol (R$/Litre)	2.3	-	2.8	-	22%

Considering the possibility of improving the persistence level of the resilience of urban mobility, Table 66 shows the weak points that should be improved in each macrozone.

Barra-Recreio needs to improve the distance to work, travel time and reduce the use of oil-based transportation. Macrozone Central shows the need to improve travel time, reduce the use of oil-based transportation and improve socio-economic conditions or reduce transportation price, because transportation costs affect personal expenses. The problem of having personal expenses affected by transportation costs are present in seven from nine macrozones, which are Central, Centro, Jacarepagua, Norte, Oeste-Rio, Praca_Maua and Sul. In relation to transportation mode, all macrozones need to reduce the use oil-based transportation modes.

Macrozone Jacarepagua shows the need for improvement in income conditions and travel time. Norte presents the need for improvement in income and distance to work. Macrozone Oeste-Rio needs to improve the income conditions, distance to work, travel time and alcohol use as fuel. Praca_Maua needs improvement in income conditions, travel time and increase in the use of alcohol as fuel. In Macrozone Tijuca, there is a need to improve the use of alcohol as fuel.

Table 66: Weaknesses of each macrozone in relation to the persistence stage of analysis - City of Rio de Janeiro

Macrozones	Income	Distance to Work	Travel Time	Fuel Type	Transportation Mode	Transportation Cover	Effect on Personal Expenses
Barra-Recreio							
Central							
Centro							
Jacarepagua							
Norte							
Oeste-Rio							
Praca_Maua							
Sul							
Tijuca							

Obs: The red blocks mark the weaknesses of each macrozone, based on the interpretation of the author of this thesis.

Table 67 considers the possibility of improving the adaptability level of the resilience of urban mobility by working through some weak points in each macrozone. Regarding the current attitude, which is related to a positive and/or negative view about urban mobility, macrozones Central, Centro, Jacarepagia, Oeste-Rio, Praca_Maua and Tijuca show that there is reluctance regarding public transportation or dissatisfaction with this system.

In the H2 threat scenario, which is related to a possible attitude facing a 50% increase of oil-based public transportation and gasoline/diesel/natural gas, macrozones Barra-Recreio, Central, Centro, Jacarepagua, Norte, Oeste-Rio and Praca_Maua present difficulty in choosing non-fossil fuelled transportations to reach work. Faced with the H3 threat scenario, macrozones Barra-Recreio, Central, Jacarepagua and Oeste Rio continues with the same problem of H2. In the H4 threat scenario, macrozones Barra-Recreio, Jacarepagua and Oeste-Rio also continue with the same problem.

In addition to these observations, it is possible to observe that there are macrozones, which are possible for people to reach for their jobs through non-fossil fuelled transportation. However, there is reluctance in these macrozones, because of the dissatisfaction and unreliability in the public transportation system.

In relation to the possibility to find a job in the same or neighbourhood district, only macrozone Centro presents a higher possibility of this happening. Although in almost all macrozones, in exception of Praca_Maua, people find it easy to reach general services, such as shopping, medical services and others. This fact deals with the job shrinkage discussion in the global economy, which leads people to choose between having more options of jobs, but with greater inequality and insecurity, or being highly qualified and having less compatible jobs, however leading to a higher social safety to less people (Wilson, 1996).

Regarding the possibility of using a bicycle to reach a train or metro station, there are three macrozones, which show some level of difficulty. They are Barra-Recreio, Jacarepagua and Norte. The others show a level of possibility to do this, however, residents of these macrozones resist travelling by bicycle to reach a train or metro station, which are related to insecurity, lack of parking spaces for the bicycle and lack of specific bicycle pathways reaching the train and metro stations. In addition, there is a potential of reducing the dependency on fossil fuels by improving the infrastructure and security to use the bicycle to reach train and metro stations.

Table 67: Weaknesses of each macrozone in relation to the adaptability stage of analysis - City of Rio de Janeiro

Macrozones	Current attitude (H1)	Attitude face to H2 threat	Attitude face to H3 threat	Attitude face to H4 threat	Possibility of finding a **job** in the same or neighbourhood district.	Possibility of finding **services** in the same or neighbourhood district.	Possibility of reaching a train or metro station by **bicycle**
Barra-Recreio							
Central							
Centro							
Jacarepagua							
Norte							
Oeste-Rio							
Praca_Maua							
Sul							
Tijuca							

Obs: The red blocks mark the weaknesses of each macrozone, based on the interpretation of the author of this thesis

Table 68 presents the transformability weaknesses based in two elements in each macrozone of the city of Rio de Janeiro. Five macrozones have low social movements, which focus on the improvement of urban mobility. In addition, two macrozones that did not receive electric-based transportation modes in the last 20 years are Jacarepagua and Oeste-Rio. Furthermore, it is possible to observe that there may be a weak relationship between social movements and new electric transportation projects. At a certain point, this confirms the fact that the planning and implementation process of this type of transportation are not done through a participative process, and it seems to follow the interests of the private sector of the economy of the city.

Table 68: Weaknesses of each macrozone in relation to the transformability stage of analysis - City of Rio de Janeiro

Macrozones	Participation on Social Movements	Electric transportation projects in the last 20 years
Barra-Recreio		
Central		
Centro		
Jacarepagua		
Norte		
Oeste-Rio		
Praca_Maua		
Sul		
Tijuca		

Obs: The red blocks mark the weaknesses of each macrozone, based on the interpretation of the author of this thesis

In addition to all these analyses, there is the issue of the capacity of the public transportation system to absorb a shift of private transportation users to the public transportation system. In the interview conducted with professionals and researchers in this thesis, a question was not included in the analysis process, which was "do you think the public transportation system has the capacity to absorb 50% or 100% of private transportation users?"

From the 10 interviewees used in this research, nine of them responded that the public transportation system is not prepared for this situation. For the adaptability stage of analysis, the capacity issue is essential, however it is a problem located in the entire city of Rio de Janeiro. For this reason, the research considers the possibility of people being able to shift to the public transportation system. Therefore, the capacity issue regarding the resilience of urban mobility faced with fossil fuel threat can be worse as presented in the results.

Figure 111 presents the described results previously and is represented geographically. In addition to what has already been commented upon, there is also the safety problem, identified in the qualitative approach, and the cover of train and metro station in each macrozone (districts with stations/total districts).

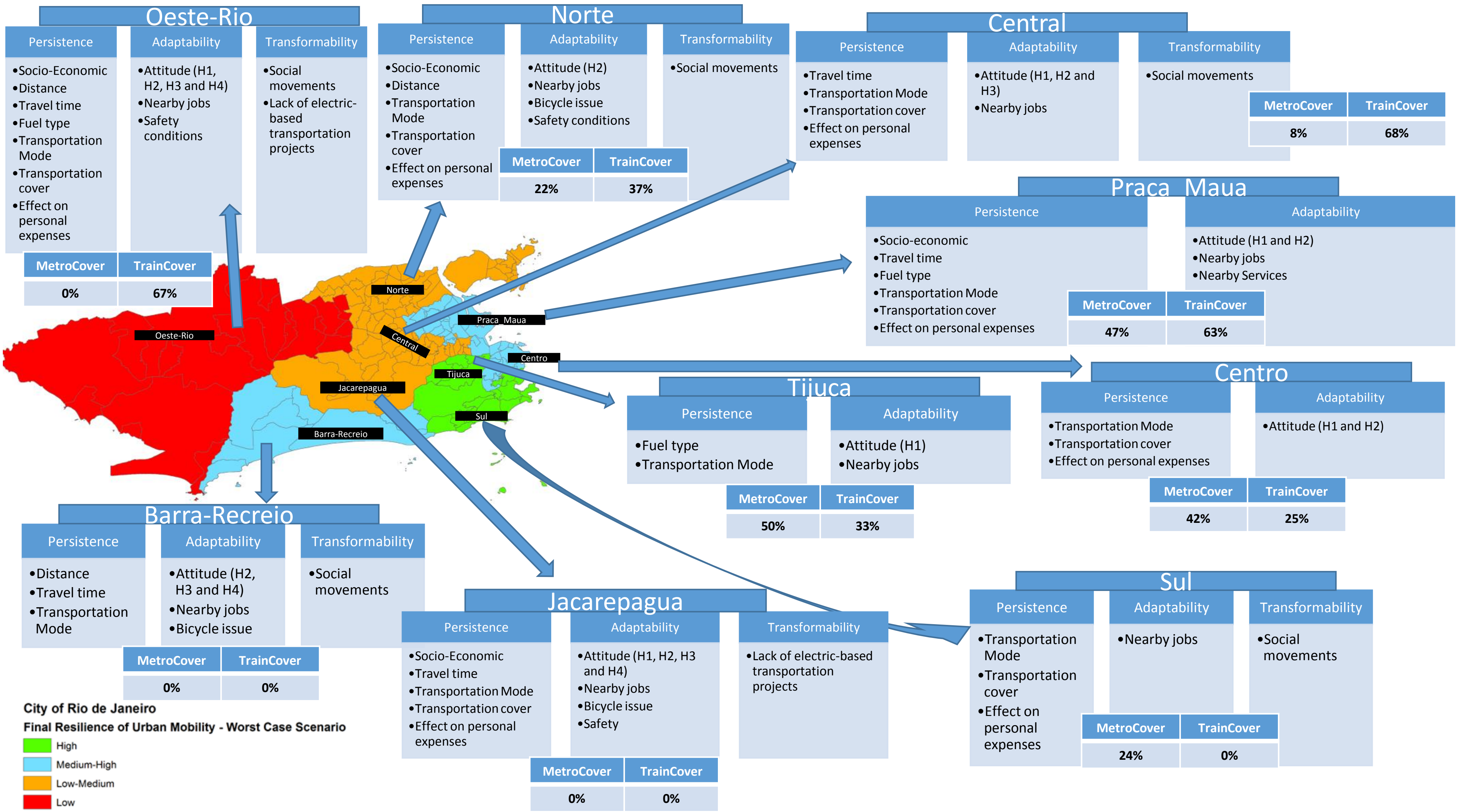


Figure 111: Representation of the weaknesess of each macrozone of Rio de Janeiro faced with fossil fuel threats for each stage of the Resilience of Urban Mobility – with Metro and Train cover (districts with stations/total districts)

In relation to each stage of the resilience of urban mobility level, Table 69 shows how each stage of the resilience is generated. This data is used to characterise the levels of persistence, adaptability and tranformability for each resilience of urban mobility level area. Figure 112 shows the results of this calculation.

Table 69: Measeures and source of data for the persitence, adaptability and transformability levels within the resilience of urban mobility

Variables	Measure	Source of the data
Persitence	Persistence level of the worst case scenario results	Calculated by the author
Adaptability	Average of the adaptability level, considering H2, H3 and H4 levels of the worst case scenario results	Calculated by the author
Transformability	Persistence level of the worst case scenario results	Calculated by the author

Figure 112 shows that the areas of low-medium and low level of resilience has lower levels of persistence, adaptability and transformability. These weaknesses of these areas, for each stage of the resilience, are presented in Figure 111.

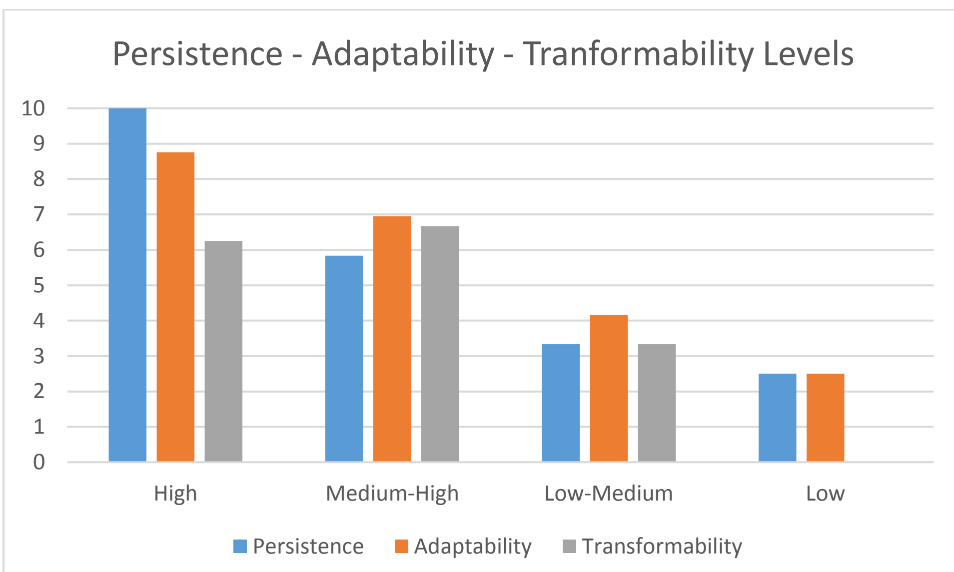


Figure 112: Persitence, adaptability and transformability levels in the each resilience level area

Besides the reached results, there is a characterization of the areas within in level of resilience based on data collected in data bank of public institutions of Brazil. From a quantitative perspective, some of the data were used along the works, and others are presented only in this final section of the thesis. Table 70 shows the variables used to characterize the areas under each resilience level. It shows, also, how they are measured and the source of the data.

Table 70: Variables used to characterise the areas within each level of resilience of urban mobility

Variables	Measure	Source of the data
Population located in the high level of resilience area (%)	Working population living in the evaluated area divided by the total working population in the city	IBGE (2010)
Earn less than two minimum salaries (%)	Working population earning equal or less than two minimum salaries in the evaluated area divided by the total working population in the same area	IBGE (2010)
Metro Access/District (%)	Number of districs with metro stations in the evaluated area divided by the total districts in the same area	MobiRio (2014)
Train Access/District (%)	Number of districs with train stations in the evaluated area divided by the total districts in the same area	MobiRio (2014)
Weighted Average Distance to Districts with Job Positions (km)	The average of the weighted average distance (centroid to centroid of districts) in the evaluated area, based on the percentage of job positions offered in each district of the city.	Calculated by the author
Residents/household	Total residents of the district divided by the total number of households in the evaluated area	IBGE (2010)
Working population/Number of Job Positions	Working population divided by the number of jobs offered in the evaluated area.	IBGE (2010) and Prefeitura do Rio de Janeiro (2014)
Stolen cars (registered in police departments in this area) (%)	Stolen cars in the evaluated area divided by to total number of stolen cars in the entire city	Governo do Estado do Rio de Janeiro (2015)
Robberies of pedestrians (registered in police departments in this area) (%)	Robberies of pedestrians in the evaluated area divided by the total number of robberies in the city.	Governo do Estado do Rio de Janeiro (2015)

Table 71 presents the characterization of the areas under each level of resilience of urban mobility of the worst case scenario. This characterization addresses the percentage of population of the city located in the areas of each level of resilience; how many people located in these areas earn less or equal to two minimum salaries; level of access to metro and train stations; average weighted distance to places that have job positions; average of residents per household; working population per job in each level of resilience area; and the percentage of stolen cars and robberies of pedestrians in the evaluated area in each level of resilience, in relation to the entire city.

Table 71: Characteristics of the areas in each level of resilience of urban mobility – considering the worst-case scenario results

Resilience Leve	Macrozones	Variables (Census)	Data
High	Sul	Population located in the high level of resilience area	16%
	Tijuca	Earn less than two minimum salaries	38%
		Metro Access/District	30%
		Train Access/District	9%
		Weighted Average Distance to Districts with Job Positions (km)	16,65
		Residents/household	2,50
		Working population/Number of Job Positions	1,97
		Stolen cars (registered in police departments in this area)	4%
		Robberies of pedestrians (registered in police departments in this area)	11%
Medium-High	Barra-Recreio	Population located in the medium-high level of resilience area	18%
	Praca_Maua	Earn less than two minimum salaries	51%
	Centro	Metro Access/District	36%
		Train Access/District	38%
		Weighted Average Distance to Districts with Job Positions (km)	17,53
		Residents/household	2,90
		Working population/Number of Job Positions	0,58
		Stolen cars (registered in police departments in this area)	13%
		Robberies of pedestrians (registered in police departments in this area)	24%
Low-Medium	Central	Population located in the low-medium level of resilience area	39%
	Norte	Earn less than two minimum salaries	61%
	Jacarepagua	Metro Access/District	14%
		Train Access/District	42%
		Weighted Average Distance to Districts with Job Positions (km)	19,07
		Residents/household	3,00
		Working population/Number of Job Positions	3,01
		Stolen cars (registered in police departments in this area)	62%
		Robberies of pedestrians (registered in police departments in this area)	49%
Low	Oeste-Rio	Population located in the low level of resilience area	26%
		Earn less than two minimum salaries	71%
		Metro Access/District	0%
		Train Access/District	67%
		Weighted Average Distance to Districts with Job Positions (km)	34,02
		Residents/household	3,16
		Working population/Number of Job Positions	3,32
		Stolen cars (registered in police departments in this area)	22%
		Robberies of pedestrians (registered in police departments in this area)	16%

It is possible to observe that the areas under low-medium and low level of resilience locates the majority of the population in the city of Rio de Janeiro, with 65% of the population of the city. Besides that, in these areas there is a higher percentage of the population that earn less or equal to two minimum salaries, which is determined as the most vulnerable socioeconomic level according to the Federal Republic of Brazil (Governo Federal, 2012). In the area with low-medium level of resilience, 61% earns less or equal to two minimum salaries, while in the area with low level of resilience, this value is 71%.

In terms of access to metro stations, the areas under low-medium and low level of resilience presents low accessibility to metro stations. In the other hand, these areas have high accessibility to train stations in comparison with the high and medium-high level of resilience areas, however the urban train system has less direct accessibility to districts with high offer of job positions. This means that it is highly probable that one must use more than one modal choice to reach work, leading to high expenses with transportation.

The accessibility to metro station, which brings higher benefits in terms of accessibility to districts with most job position, can be widened through the implementation of alternative electric mobility solution. Considering the unfavorable slope condition for long cycling trips, there may be a potential for the city to benefit from the use of e-bikes or pedelects (bicycle with electric motors), which could allow one to overcome unfavorable slope condition and allowing a higher distance trip (Rothfuss & Le Bris, 2013). Therefore, these types of electric mobility solutions have the potential to design more sustainable and also resilient mobility systems (Rothfuss & Le Bris, 2013).

The weighted average distance in the low-medium and low level of resilience area also presents higher values in comparison with the high and medium-high resilience areas, leading to higher expenses with fuel costs, eventhough one could use alcohol. These areas also present higher number of residents per household. In relation to job positions, the low-medium and low level of resilience areas has less jobs per working population, approximately, 3 working residents for 1 job position.

Besides these information, it was also collected criminality statistics, regarding stolen cars and robberies of pedestrians. The areas with low-medium and low level of resilience presented higher percentage of stolen cars and robberies of pedestrians in comparison with the areas of the other levels of resilience.

In overall, it is possible to observe that there is a need for the city of Rio de Janeiro to bind transportation and urban planning. The socio-spatial characteristics of the city presents high inequality levels in terms of income, infrastructure, services and jobs. The chalegens that lies ahead for the city of Rio de Janeiro, are related to buiding a city with less inequality regading weaknesses identified in this thesis. Furthermore, attending to sustaibable goals, leading to fair social, economic and environmental equality.

9.2. Accomplished Goals in this Thesis

This section addresses the goals determined at the beginning of the thesis. In other words, it presents whether the questions and objectives adressed this thesis have been reached along this entire research. The approach chosen in this section is presenting the key questions of this research and replying whether they were responded to or not, while adding a resumed argument.

1. **How important are fossil fuels in the current society?**

In **CHAPTER 2**, this question has been addressed through an extensive review of how different sources of energy changed technology, modes of production and the society's trends. In this chapter, it was observed that society is significantly dependent on fossil fuels, because it is a resource applied to several sectors, including transportation. The trends show that there is a higher possibility of the energy sector of increasing the use of renewable energy source. The transportation sector trends show contrary trends, where there are lower values of inclusion, for the next few years of non-fossil fuel sources in this sector.

2. **What is the relationship between urban mobility and fossil fuels?**

Understanding the trend of the transportation sector and the difficulty of implementing new and more efficient technologies, it is possible to observe that solution regarding mobility follows the interest of the private sector, in which there is a strong effort to develop affordable solutions for transportation companies. On the other hand, there is less effort of the public sector to deepen the understanding of the spatial and social characteristics of the urban environment, which could generate cheap and effective solution for the urban mobility and reduce social inequality.

3. **Is there an existing solid concept on the resilience of urban mobility?**

As presented in **CHAPTER 3**, in 2014, a search for the concept of the resilience of urban mobility was done. It was difficult to find a solid concept and this lead to the construction of a concept, based on a varied literature review, which deals with urban space, economic geography, energy security, urban sociology, urban resilience and sociology of mobility and transportation. The concept built in this thesis takes a social perspective, different from other perspectives, which appeals to the effects of fossil fuels' use on climate change and consequently, the climate change effect on society. This research deals with a possible first stage of a fossil fuel threat, which deals with social and spatial characteristics of the city.

4. **If there is not a solid existent concept, how to conceptualise it?**

The chosen path to conceptualise the resilience of urban mobility is by exploring how different scientific fields look regarding transportation and mobility issues within the urban environment. The understanding of the different perspectives brings an idea that there are two groups of elements, the direct and indirect influences that can encourage urban mobility.

The direct influences are related to the reproduction of the needs of the society, which deal with their view on urban space and opportunities. Indirect influence deals with what urban space has to offer to the society and how urban space is planned according to the needs of the society. Furthermore, the concept of resilience was reviewed and it is important to understand which view of the resilience concept combines with the view of urban mobility. Lastly, it was determined that the resilience of urban mobility faced with a possible threat has three stages of analysis: persistence adaptability and transformability.

Each stage of the resilience of urban mobility concept has a definition. Based on the definition of each stage, it is observed which elements of the direct and indirect influences fit into each stage of the analysis, generating a final model of the resilience of urban mobility.

5. **What elements of society are involved in the resilience of urban mobility?**

The elements involved in the resilience of urban mobility from the direct influence perspective are socioeconomic conditions, origin/destination, attractiveness of places (job and services availability), social movements, right to urban mobility, private transportation use and attitude towards the mobility conditions. The elements regarding the indirect influences are built environment, public transportation and public/private sector.

6. **What is the difference between resilience of urban mobility to sustainable mobility and energy security?**

The difference between sustainable mobility and resilient mobility is presented in **CHAPTER 5**. Sustainable mobility has social, economic and environmental concerns. Resilient mobility is concerned with social and economic threats, generated by natural disasters, technical and human errors.

The intention of not considering the environmental aspect directly in the resilience of urban mobility framework is to value the function and scientific thoughts of the sustainable approach. Valuing the function of the resilience approach is related to the sudden possible changes or threats and how these threats can be avoided through social, economic and urban improvements.

In addition to this information, it is possible to understand that these two concepts are complementary. Because, when dealing with fossil fuel threats, e.g. a social group can resist this matter through high wage conditions, which would allow people to deal with price increase, without being socially affected and enabling one to maintain mobility patterns. On the other hand, it is possible to resist fossil fuel threats by offering a sustainable transport system, which would not be affected by these threats. To conclude, the ideal scenario is to have sustainable and resilient solutions to walk together. However, in today's society, it is observed that there are cities that still invest heavily in fossil-fuelled transportation modes, including both public and private. As an example, Rio de Janeiro presents the case study that has been explored in this research.

7. **How can the resilience of urban mobility be measured, faced with fossil fuel threats?**

Based on what has been developed in **CHAPTER 6**, the resilience of urban mobility can be measured through two approaches, quantitative and qualitative methods. The quantitative method is based on data that are already available at the federal and municipal government levels, which are transportation system and infrastructure, transportation price, income levels, matrix of expenditure, available job positions and distance between districts centroids (origin and destination).

The quantitative method deals with the persistence and adaptability stage of analysis. The idea is that when faced with fossil fuel threats (e.g. sudden increase in price or reduction of the availability of fossil fuels), citizens of the city are the first to be affected, while private markets will try to adapt, based on investment management as have been seen in the history of capitalism in cities. This logic is based on how people would be affected socially and spatially, through possible mobility options and spatial characteristics. This can be exemplified through the possibility of the person to continue to reach the same destination, by the same means of transportation without being affected socially (persistence) or by using others means of transportation (adaptability), which create better conditions to resist threats. The other factor taken into consideration is the possibility of changing the workplace, preferably in the same or neighbourhood district when they live.

The qualitative approach deals with gathering of data by applying questionnaires to transportation users. The data gathered are socioeconomic information, attitude, origin/destination, possibility in finding jobs and services near residence and mobility patterns. This data also involves persistence and adaptability stages of analysis, however, there the approach to this data is different, because it deals with the interpretation and coding of data, to be able to measure the level of persistence and adaptability within the resilience of urban mobility.

The transformability stage of analysis deals with the application of questionnaires to transportation users, interviews with professionals and researchers and gathering data from official documents. This stage analyses the efforts to change current mobility opportunities, through planning and implementation of new mobility solutions. These results are generated through interpretation and coding of data.

At the end of all analyses, it is possible to join the information of persistence, adaptability and transformability of the resilience of urban mobility, generating a final level of resilience.

8. How can the resilience of urban mobility be classified into levels?

In this thesis, the resilience of urban mobility is classified into five levels: low; low-medium; medium; medium-high and high. However, for each level, there can be different combinations of data levels, which can generate the same or different results in different parts of the city. It is important to relate the results with the elements that are more vulnerable when faced with fossil fuel threats. Moreover, the results represent that there is a level of vulnerability, which is related to one or more elements, rather than specific results when two areas have the same level of resiliency.

The classification of the levels is based on an interval of results, such as from 0 to 4, or from 0 to 10. These intervals are divided equally into five intervals, determining the levels of resilience of urban mobility and for each stage of this resilience: persistence, adaptability and transformability.

9. **Is it possible to predict the resilience of urban mobility when faced with hypothetical scenarios of fossil fuel threats?**

This research shows that it is possible to build a methodology where the fossil fuel threats are hypothetically presented. This is possible under the condition that the variables proposed in this research are accessible and collectable. **CHAPTER 8** provides detailed results of the proposed methodology, applied to the city of Rio de Janeiro, when faced with hypothetical fuel threats.

10. **Is it possible to predict the resilience of urban mobility, based on improvements, which will be implemented in the future?**

This thesis shows that it is possible to predict the resilience of urban mobility with possible future improvements. This is because it is closely related to the transformability stage of analysis, which considers possible future projects. In addition, the requirement of the society to new projects, by observing how people engage with social movements in practice, e.g. whether people participate in protests and demonstrations that have the interest of forcing the public and private sector to improve urban mobility.

11. **What are the benefits for a city, when approaching the resilience of urban mobility?**

The benefits of approaching the urban mobility under the resilience perspective are that, as the sustainable discussions increase, the resilience approach can complement and give a more holistic view of the urban mobility problems and solutions. The resilience approach, proposed in this thesis, has the potential to identify vulnerable elements in the city when faced with economic and energy crisis, considering social and spatial characteristics. While the sustainable approach has some interceding concern, along with meeting environmental criteria, it aims to reduce the effects on the transportation sector in the case of climate change impacts or increase in the level of local pollutants.

Furthermore, policies could be developed to fulfil short- and long-term solutions, covering precise decisions for the problems related to urban mobility. Solutions related to urban mobility should not be limited to how much greenhouse gases are emitted, but also to whether people have an acceptable level of dignity regarding urban life with an acceptable quality of service offered by the transportation sector and urban structure.

9.3. Limitations and Further Need for Research

It is understood that the advances in the scientific community today are more dynamic, with the improvements in the internet service and increase in the quantity of journals, leading to higher global scientific productivity. For this reason, the scope and depth of literature review could still be widened for further research. This can be seen as the first limitation of this work, which was completed within three years.

Other limitations are related to the case study. In the qualitative analysis, the sample size of 369 respondents with 95% of confidence level presented 5.10% of error margin, which could be considered an acceptable statistical sample size. However, geographically this sample was not equally distributed, which can influence the validity of the results in terms of the spatial approach. On the other hand, the quantitative approach allowed a representative sample size and geographically, however, there is a lack of qualitative data. Beyond this limitation, not all responses from professionals and researchers gathered from interviews were used in this research. Therefore, for further research, it also proposed to include the answers from the questions which were not included in this research, because of the short time and complexity to put together the analysis of all information gathered.

Furthermore, only one case study was applied with a proposed methodology in the thesis. It is proposed that further case studies should be done to test the applied methodology, aiming to increase the validity of this methodology to evaluate the resilience of urban mobility. Different case studies should also mirror different types of urban mobility systems in different environments in terms of development level, modal split patterns etc.

Beyond the need for further cases studies, it was observed that the scale of the city could be a significant obstacle for the research. This is because, e.g. in the case of Rio de Janeiro, a city with approximately six million inhabitants and with 1.255 km², the complexity of urban life and social relations is quite high. In this case, the amount of data associated with such a study and variety of interrelated elements increase the difficulty of understanding reality as it is. In addition, further research is proposed to benefit from the identification of the vulnerable areas of the city, based on the proposed methodology. It is also advisable to perform local studies at the district scale, with a representative sample size, to confirm the problems identified and deepen the understanding about the local problems and solutions, respecting the social and spatial differences in the city.

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