

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING



**EVALUATING THE SUSTAINABILITY OF URBAN MOBILITY
AND TRAFFIC GROWTH IN CITY OF ADDIS ABABA**

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B.Sc. (Civil Engineering, Addis Ababa University, 2014)

**A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the
Requirements for the Degree of Master of Science in
Road and Transport Engineering**

Advisor: **Bikila Teklu (PhD)**

May , 2019

Addis Ababa, Ethiopia

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Ababa

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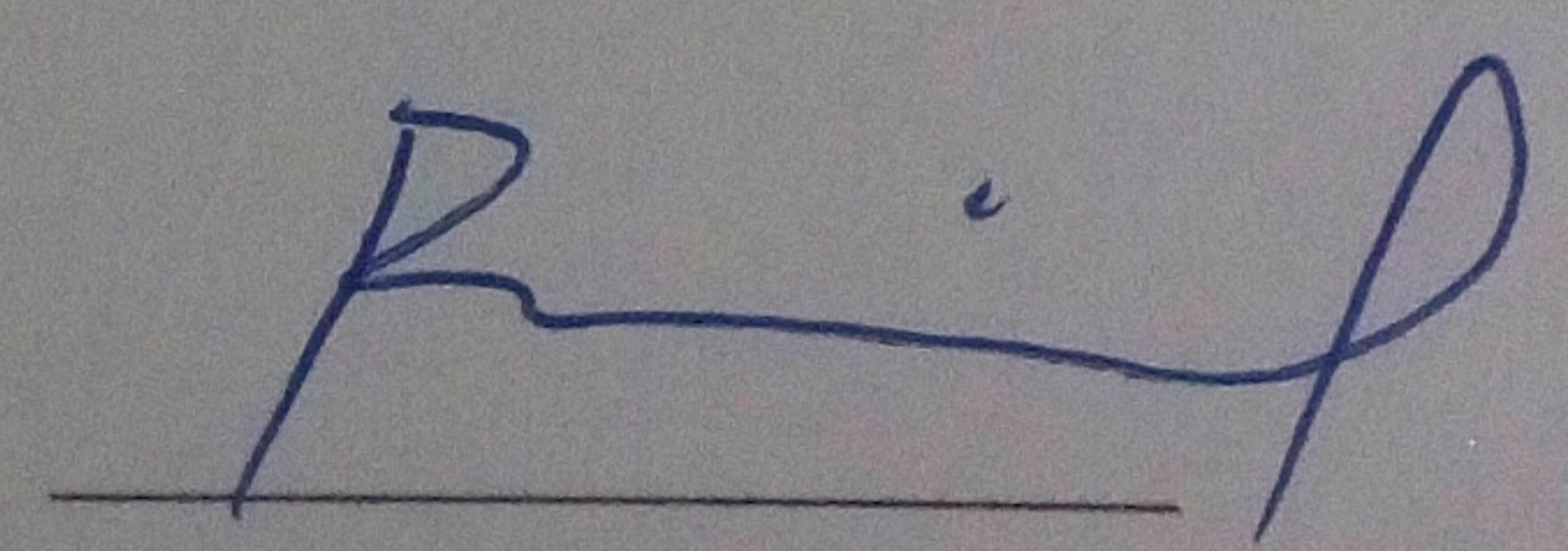
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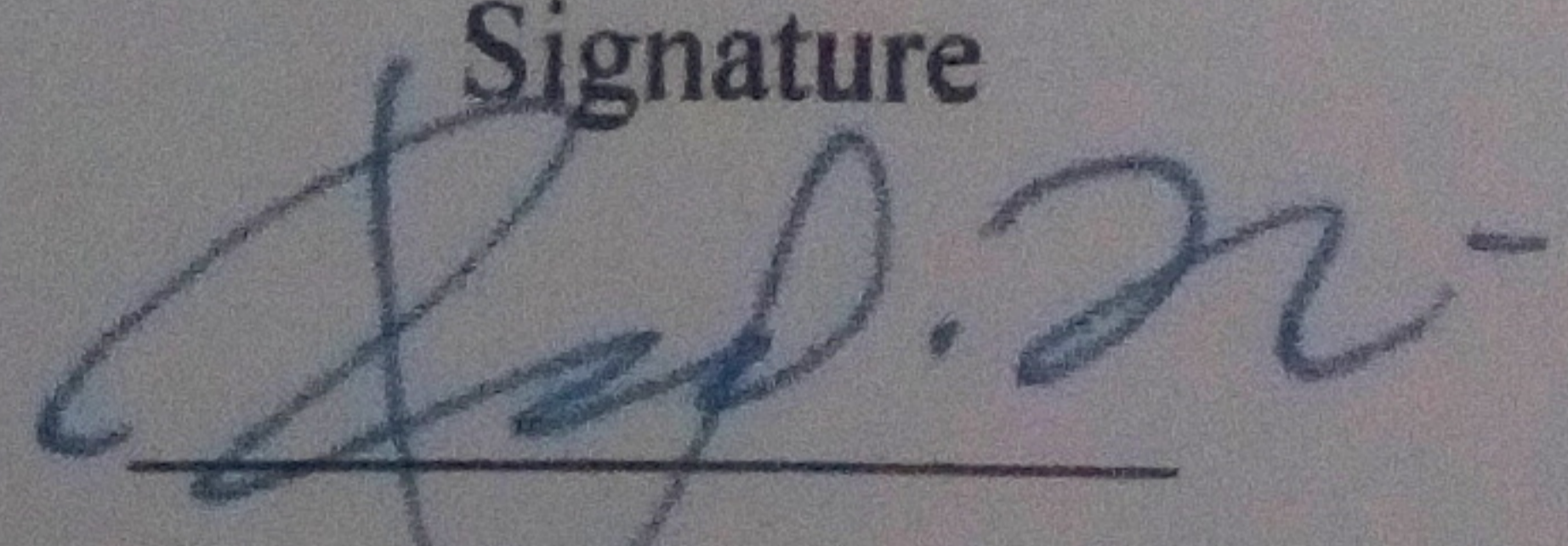
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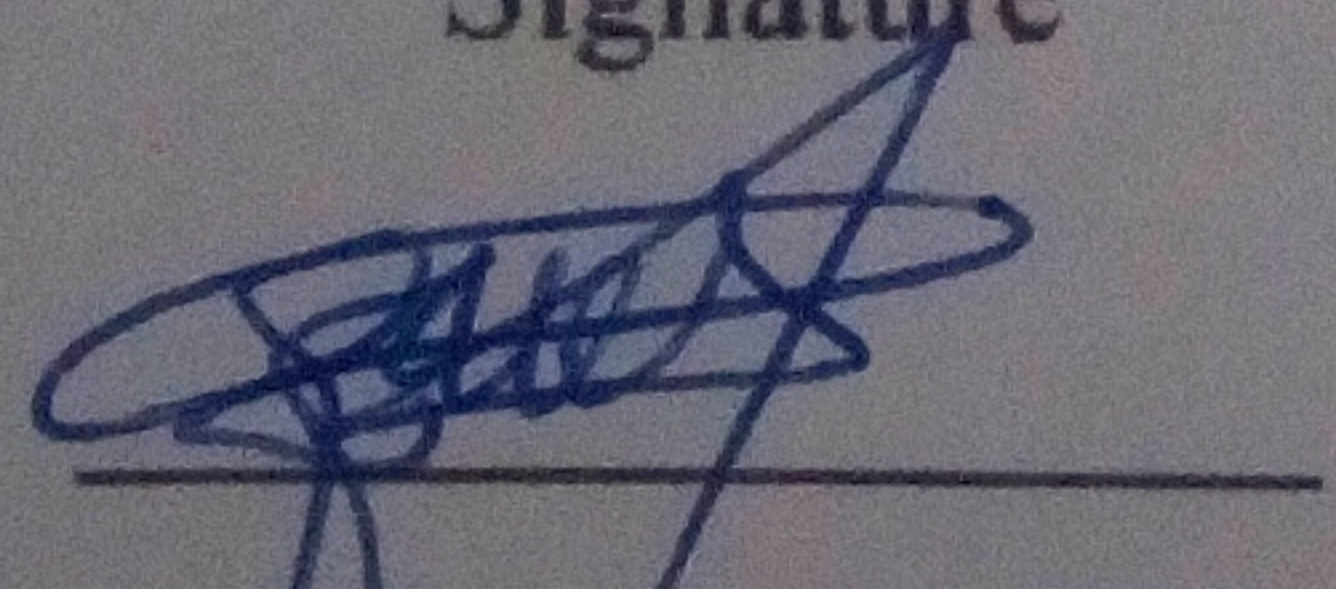
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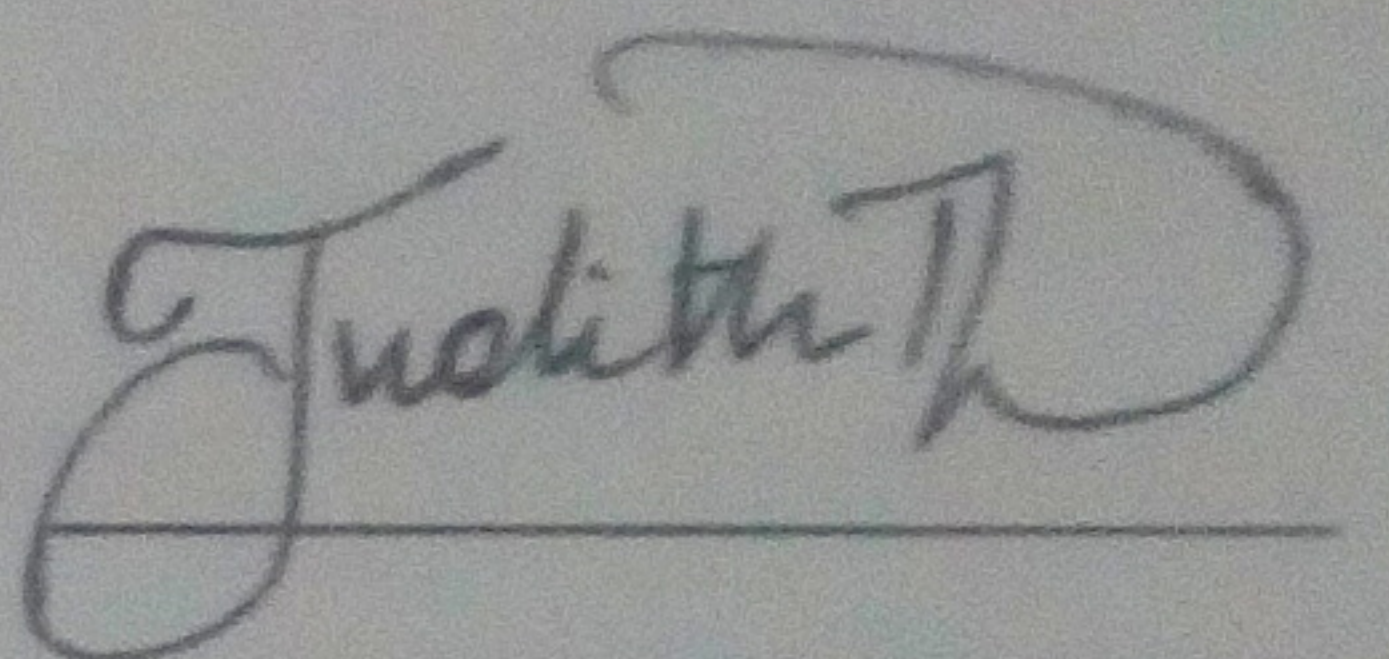
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UNDERTAKING

I, the undersigned, certify that research work titled “Evaluating the Sustainability of Urban Mobility and Traffic Growth in City of Addis Ababa” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources, it has been properly acknowledged / referred.

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Date: May 2019

ABSTRACT

It has been long since mobility became a major issue in Addis Ababa following the enormous horizontal expansion of the city boundaries because of the rapid population and income growth. The current transportation problem in Addis Ababa is at its boiling point, and worsening by the day despite the government's attempt to address it. As transport system is an important part of a city, success in insuring mobility can even be an indication of how well the city really is organized. Failure to provide well-functioning transport system causes growing social, economic as well as environmental problems. Spatial sprawl, infrastructural development and increasing vehicular number are concurrent trends that need coordination among actors and policies for sustainable development. Although there are studies conducted to understand and solve the problems related to motorized transport in the city, most of them focus on the conventional approach of improving the physical infrastructure of the transport sector to enhance the service provision by constructing highways, extending road networks and increasing the number of fleet. Measures that differ from the ones with the conventional focus of congestion and mobility should be assessed. The general objective of the study is to evaluate sustainability of transport system in Addis. Although Sustainability is difficult to be measured directly, it can be evaluated through a system of parameters and indicators constitute part of this process. A procedural framework was developed to select *potential local indicators* for the current work. Data were collected using different techniques at various stages. Existing database, unprocessed data from surveys and processed data from spatial studies were among the sources used for data gathering. Indicator parameters are obtained by means of formula calculation, extraction from previous studies or other methods. The score of indicators are then calculated based on the parameter value. In line with the results from the analysis, the sustainability of city transport system scores 2.69 out of 5 suggesting weak sustainable mobility conditions. The results of this application highlight the priorities for the improvement of city's sustainable mobility conditions as presented using a spider chart, which gives the disaggregated overview of the mobility performance. Consequently, a shift towards more sustainable modes of transport like public and non-motorized transport is needed. The trend analysis on vehicle growth also confirmed lack of attention for these modes. Most of the trends indicate that the current traffic growth is unsustainable.

ACRONYMS

AA -Addis Ababa

AACA -Addis Ababa City Administration

AACATA -Addis Ababa City Administration Transport Authority

AACG -Addis Ababa City Government

AACRA -Addis Ababa City Road Authority

AAU -Addis Ababa University

AU- African Union

BoFED -Bureau of Finance and Economic Development

BRT - Bus Rapid Transit

CSA - Central Statistics Agency

EC- Ethiopian calendar

ERA - Ethiopian Road Authority

GDP - Gross Domestic Product

LRT - Light Rail Transit

NMT - Non-motorized transport

OECD - Organization for Economic Co-operation and Development

PT - Public Transport

STI - Sustainable Transport Indicator

TRB - Transport Research Board

UNDP- United Nations Development Program

UNECA - United Nations Economic Commission for Africa

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CHAPTER 1: INTRODUCTION

1.1. Background

According to Zietsman et al (2000), “sustainable development is development that ensures intergenerational equity by simultaneously addressing the multi-dimensional components of economic development, environmental stewardship, and social equity. It is a dynamic process, which considers the changing needs of society over time. Sustainable development can be seen as a continuum, representing various degrees of sustainability. It must, however, be achieved within resource, environmental and ecological constraints.”

Sustainable transportation is an expression of sustainable development in the transportation sector. Sustainable transportation concepts fit into the dimensions of economic development, social equity, and environmental stewardship and include issues such as safety and security, employment, productivity, accessibility, equity, environmental protection, etc. The challenge for transportation planners and decision-makers is to implement these concepts and principles.

The actual implementation of sustainable transportation concepts has been disappointing, and successes are few and far between. Sustainable transportation can be considered as one of the most debated but least implemented concepts in urban and transportation planning. Deficiencies can to a large extent be addressed if the concepts associated with it are clearly defined and quantified. This is an even bigger problem in developing countries where technology and expertise trail far behind that of developed nations.

Sustainable transportation has not been adequately quantified for some of the following reasons (Zietsman, J. et al (2002)):

- Sustainable transportation is a fairly new concept for which the objectives and scope of activities are unclear;
- there is a lack of guidelines for identifying appropriate performance measures;
- the current state of the practice in terms of modelling and planning techniques are not able to adequately quantify sustainable transportation performance measures; and
- Even if sustainable transportation performance measures can be quantified, it is unclear how to make trade-offs and decisions in a consistent and unbiased manner.

As transport is the engine of social and economic activities, the provision of competent and efficient transportation system is of paramount importance for cities where they are the centers of urbanization and propellers of national and global economies. Urbanization is a challenge when coupled with congestion and automobile oriented-development practices. Addis Ababa, the capital city of Ethiopia and the seat of many international organizations with more than 100 embassies, has now become one of the fastest growing cities in sub Saharan Africa. The city is populated by individuals from various districts of Ethiopia and undergoing a high rate of urbanization. This process of rapid urbanization has resulted in the increase in the size of the population and the physical expansion of the city which imposes intense pressure on the urban infrastructures, particularly on transport.

As history of many cities shows, socio-economic growth usually accompanied with an increasing demand for mobility and transportation. Following the economic development in the country, Addis has become the economic hub of the nation due its geographical as well as political significance. Accordingly, many financial and commercial institutions and about 85 % of the manufacturing industries of the country are located inside and at the periphery of Addis Ababa. Such rapid socio-economic development in the city also creates a huge increase in travel demand and length of the trip.

Addis is already in peak pressure of providing competent transportation infrastructure and service that can absorb the pressing demand of the ever-growing population. In light of this, the city is striving to overcome the current transport problems and the inevitable future challenges through the introduction of LRT and BRT lines and development of high-profile road projects.

To sum up, the transport system is an important part of a city and success in insuring mobility can even be an indication of how well the city really is organized. Mobility in Addis Ababa becomes a big issue as the city keeps expanding horizontal because of the increasing wealth and population. Failure to provide well-functioning transport system causes growing social, economic as well as environmental problems. These points emphasize the needs to recognize the effects of transport in planning in urban areas and integrate the policies. Spatial sprawl, infrastructural development and increasing vehicular number are concurrent trends that need coordination among actors and policies for sustainable development.

1.2. Motivation and Problem Formulation

Transportation plays a key role in determining the socioeconomic development and shaping the spatial development framework of the city. It is also a fundamental means for residents to fulfill their various activities. The current transportation problem in Addis Ababa is at its boiling point, and worsening by the day despite the government's attempt to address it. Due to different reasons, the city administration could not provide adequate urban transport system to cope up with the rapid increase in population with annual growth rate of 3.8% (AACATA).

For the city's people, getting around is challenging. Getting to work is increasingly problematic in large part because of the tidal wave of minibuses that have arrived to take the place of faltering public bus services. Both of the public transport components of the city, shared taxis and city buses, are proved to be incapable of meeting the demand. Commuters walk or resort to largely unregulated and informal services that are dull, unsafe, uncomfortable and unreliable. The taxi zoning system introduced was anticipated to solve the problem, but it did not. Among the major factors contributing for the problem is the imbalance between the limited amount of service providers and the ever growing number of commuters.

The urban transport system failed to reach the increasing demand generated. The mobility needs created in the peripheries of the city create enormous pressure on the transport sector. This problem could not yet be solved by expanding the road networks, which end up encouraging more car ownership, hence increasing congestion, pollution and commuting time. As a result of the limping public transport system and other reasons the number of cars in the city is increasing, though import taxes are extremely high.

A few years ago, for many people, cars were considered a luxury item, a symbol of high class status. However these days, with expansion of middle class, many consider cars a basic necessity as it's regarded as means of facilitating businesses and ease everyday activities and transactions. The skyrocketing inflation made some believe that buying vehicles is a sound **way of asset accumulation** as cars are generally considered to have low depreciation rates and can even gain monetary value over time. Plus other forms of ownership like houses are expensive in Ethiopia, particularly in Addis Ababa and the only viable option to store value for many middle class societies is through buying cars.

The rapid growth of cars to the roads of Addis Ababa has its own social, economic and environmental effects - both negative and positive. Road coverage of the city has also grown but despite this growth, traffic jams in many parts of the city and bottlenecks at roundabouts and traffic lights have become a daily challenge for everyone. Many feel the number of cars on the roads is the main factor contributing to road congestion and there aren't enough roads for the cars coming to the country, particularly to Addis, others argue that the roads available are enough for the cars in the city but the lack of efficient traffic management systems has exacerbated the problem. Officials at the Addis Ababa Transport Authority also said the number of cars in the city compared to other neighbouring countries is still small. Public transportation is also the most important mode of motorized mobility for the large majority of the city's population. There are various formal and informal operators of the public transport mainly operating on individual basis and most of them are **low capacity vehicles**.

As transport system is an important part of a city, success in insuring mobility can even be an indication of how well the city really is organized. Failure to provide well-functioning transport system causes growing social, economic as well as environmental problems. These points emphasize needs to recognize effects of transport in planning urban areas and integrating policies. Spatial sprawl, infrastructural development and increasing vehicular number are concurrent trends that need coordination among actors and policies for sustainable development.

Urban transportation system must balance two basic needs: Transportation must continue to contribute for economic development and human welfare as well as mitigation of transportation negative effects. In other word, our transportation systems should be made more sustainable.

1.2.1. Statement of problem

The ongoing urbanization and economic growth mean that more people will be making more trips across longer distances and lead to more motorized traffic. Increased motorization due to the enhanced demand for personal mobility leads to increase in congestion, accidents and pollution. The city of Addis Ababa is striving to bridge the gap between the transport demand and supply. Large-scale road projects are underway to improve the quality and capacity of the existing road transport infrastructure and hence the service provision. But given the low performance of the transportation system in Addis Ababa and the trend it is practicing, it requires further improvement.

Road network infrastructure and transport service provision need adjustment in planning, designing, management and operational practices. The city is at a crossroad in terms of the choice of transportation priorities that set the direction and framework for future development. The conventional way of planning and designing urban transport infrastructure result in the vicious circle of congestion, as this practice will be accompanied by a rise in the use of car and need of more roads. This causes spiral of negative externalities and further distorts urban forms that severely undermines environmental, social and economic sustainability of cities. Measures that differ from the ones with the conventional focus of congestion and mobility should be assessed.

1.2.2. Research Questions

- What kind of indicators should be used to quantify and know the level of sustainability of Addis Ababa transport system?
- To what degree/extent does sustainability practiced in the transport sector?
- What is Addis Ababa's sustainable transportation level?
- What are the real and perceivable challenges of the city of Addis Ababa with regard to sustainability in the contemporary practice of urban transport system?
- What are the major problem areas for realizing sustainable transport system?
- How can Addis replicate and implement sustainable urban mobility practice?

1.3. Purpose, Aim and Objective

The goal intended to be attained by this study is threefold. First, it is to demonstrate a methodology for assessing a broad range of sustainability parameters using relevant spatial and environmental analyses. Second is to determine the essential elements of transportation system sustainability and to consider appropriate indicators for evaluating it. Third, it is to propose a decision support tool, which enables decision makers to incorporate sustainability considerations in transportation planning.

The research aims to assess and evaluate the sustainable mobility conditions in Addis Ababa, taking into account the relevant available indicators from the international literature review and selecting and adjusting them properly for local use. The results of the study highlight the priorities for the improvement of the specific city's sustainable mobility conditions.

Overall, the **general objective** of the study is to evaluate sustainability of transport system in Addis Ababa and to develop and apply a methodological approach through which indicators for sustainable transportation can be identified, quantified, and used. The measures that are selected for this purpose are destined to address the dimensions of sustainable transportation (economic, social, and environmental factors). It could therefore, be expected that these measures would differ from the ones with the conventional focus of congestion and mobility.

The **specific objectives** are as follows:

- Develop a framework for identifying required sustainable transport indicators
- Select and quantify relevant local sustainable transport indicators
- Develop an index and level of sustainable transportation in Addis Ababa
- Measure traffic growth sustainability in Addis Ababa
- Highlight major problem area and priority of improvement in realizing sustainability goals for the city of Addis Ababa

1.4. Conceptual framework

The research is designed based on comprehensive literature review that is used in the formulation and identification of real world problem. The concepts are then synthesized and operationalized in practical study to construct theoretical framework that serves as research methodology and guiding principle. Figure 1-2 also shows the procedure followed in conducting the research.

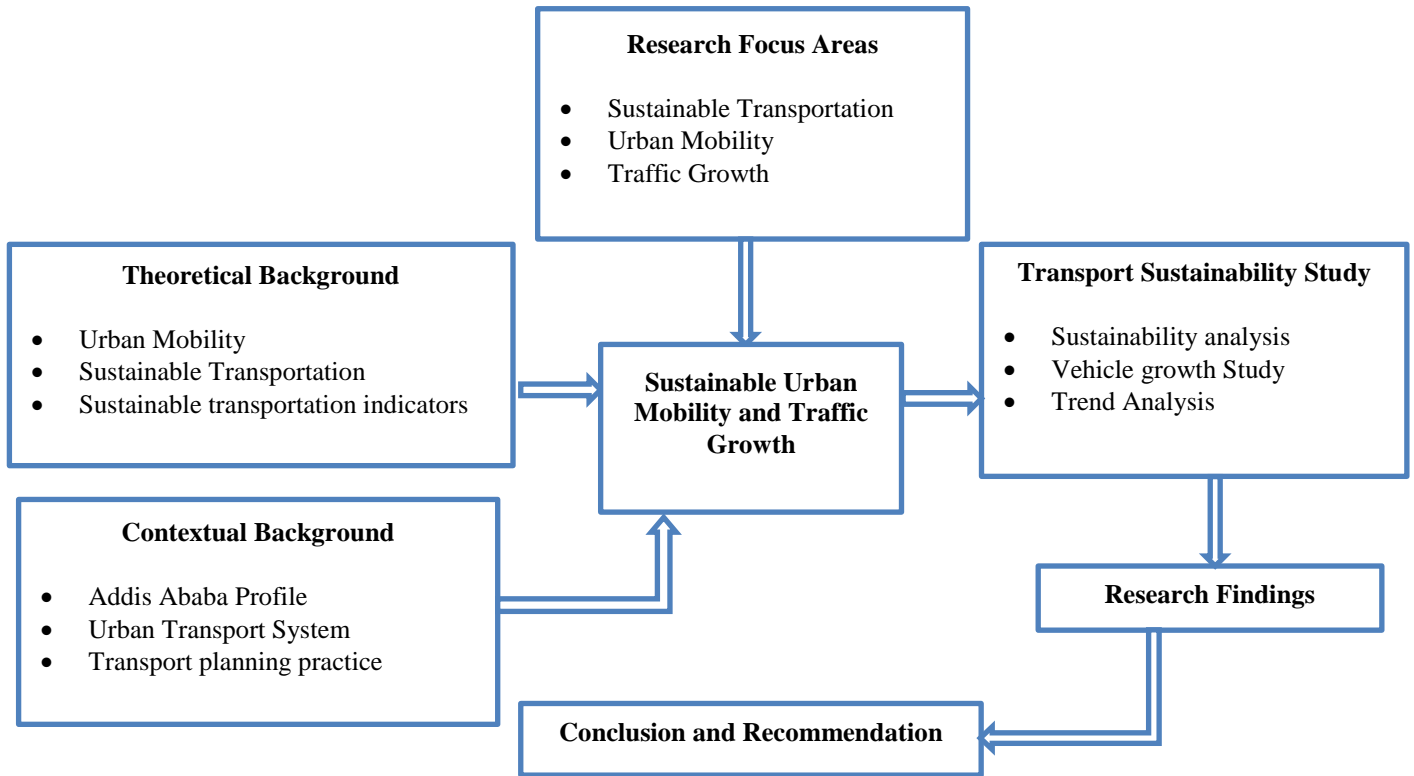


Figure 1-1: Research Design

1.5. Methodology

The study type dictates the research design. Commonly, the study objectives can be achieved through a number of alternative designs. The research will be conducted both by using observational and analytical method. The research strategy adapted for the research is a qualitative study of descriptive type, which explains the existing condition, diagnoses a situation and quantifies the state at end. The overall approach that was followed is; establishment of the basis of the research, collection of necessary data, analysis and finally conclusions and recommendations were made based on the findings. Figure 1-3 highlights the overall methodology that summarizes the three phases that were followed during the accomplishment of the research process. The in-depth methodologies developed for each phase are presented in their respective chapters.

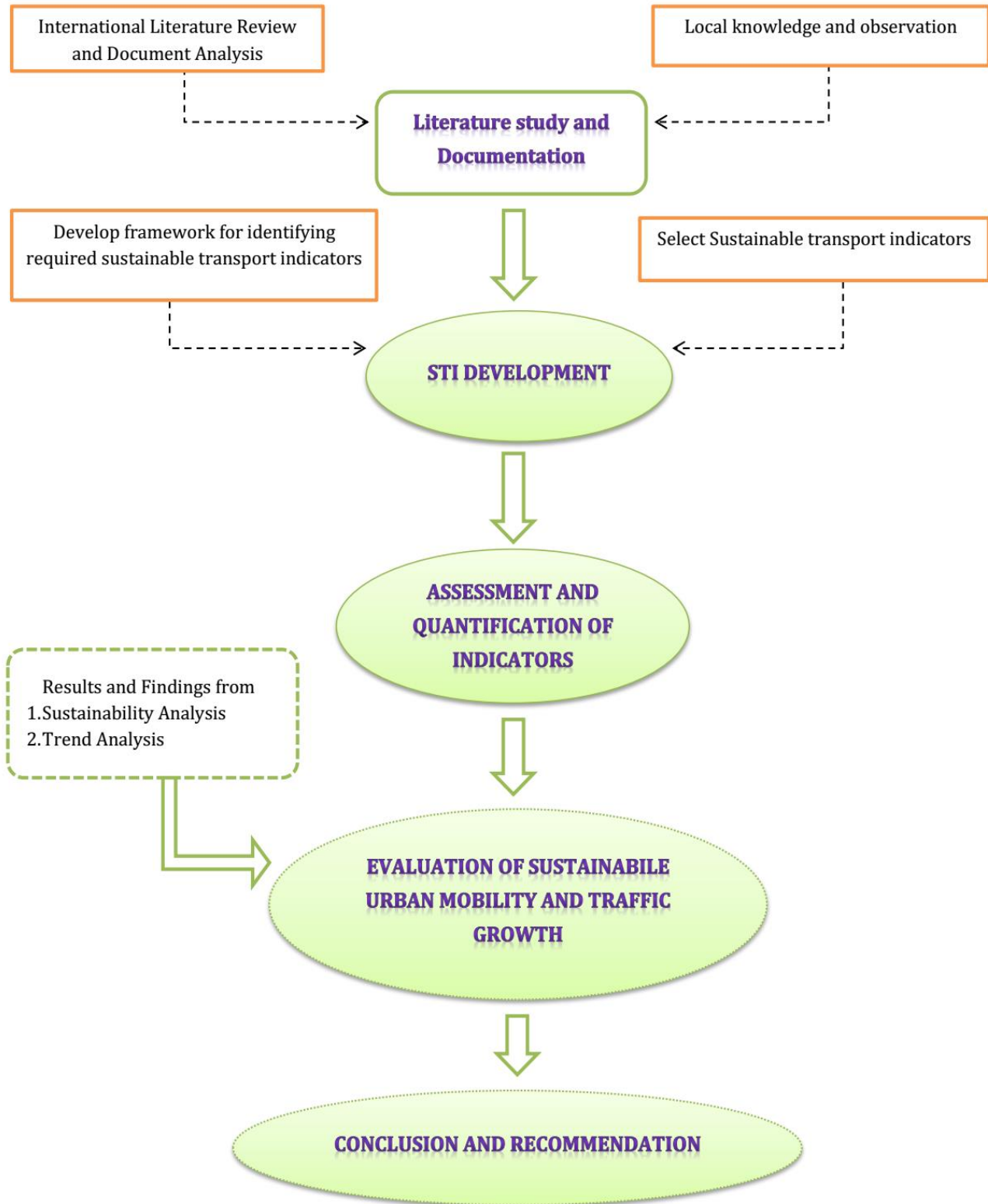


Figure 1-2: Conceptual framework

Methodology Highlight

Phase 1: Sustainable Transport Indicators (STI) and Database Development

- International Literature Review and Document Analysis
- Develop framework for identifying required STI
- Identification and Selection of appropriate STI
- Identify the data needs and requirements for candidate indicators and identify possible sources for obtaining required data and Data collection
- Study appropriate modeling/calculation techniques

Phase 2: Assessment and Quantification of Selected Sustainable Transport Indicators

- Grouping of indicators under sustainability objective theme
- Singing of indicators with reference to positive and negative impacts.
- Normalizing of the indicators for sustainability calculation.
- Analyze and quantify the sustainability.
- Results and Findings from Sustainability Analysis and Trend Analysis will lead to the evaluation of sustainable urban mobility and traffic growth

Phase 3: Conclusion and Recommendation

- Conclude on sustainable mobility condition/level of Addis Ababa evaluated using a representative selection of indicators
- Demonstrate use of sustainability in evaluating transportation
- Recommend what needs to be done for future (for governmental authorities, policy makers, professionals as well as for researchers to fill the gaps and limitation of the work)

Figure 1-3: Research methodology highlight

1.6. Scope and Relevance of the study

In this context, the scope of the current paper comprises the presentation of a methodological approach for assessing and evaluating the sustainable mobility conditions in city of Addis Ababa taking into account the international literature review and adjusting it for implementation.

The scarcity of data on travel characteristics, income and expenditure are serious limitations when conducting a research in developing countries and Addis Ababa is not an exception. The research was severely hampered by this problem. The indicator selection process includes a data driven technique on behalf of other criteria. (The detail can be found in chapter 4: how data availability affects and limits the work). The constant reshuffling of public organization in the city and country at large made it difficult to trace important historical decisions (poor institutional memories) that have been made in the past. Therefore, trend analysis can be made only for some indicator parameters.

Concern about sustainability can be considered a reaction to the tendency in decision making to focus on easy-to-measure goals and impacts, while ignoring those that are more difficult to measure. Sustainable decision-making can therefore be described as planning that considers goals and impacts regardless of how difficult they are to measure. Therefore, the research will be relevant for refining sustainability practice and know in what level it is in general. In specific, it is expected to benefit the following spectrum of target groups (public authorities, decision-makers, organizations and professionals)

- Addis Ababa Transport Authority can make use of the document to strengthen the role of public transport and to design strategic urban planning.
- Addis Ababa City Road Authority (AACRA) will find it useful to improve the current practice of road design and planning so as to design complete streets roads with dedicated bus lanes and adequate pedestrian facilities.
- Professionals and practitioners in respective disciplines (architects, urban planners, and engineers, individuals and private companies) engaged in local planning of urban centers and city development will also benefit from this research.

1.7. Organization of the thesis-structure of the paper

The paper is organized in six chapters and the content of each chapter is briefly described as follows.

Chapter 1- Introduces the content of the paper, general problem field of the study, identifies research problem, defines research questions and objectives and highlights the theoretical framework, methodological design as well as scope and relevance of the work.

Chapter 2- reviews different literatures that are related to the definition, evaluation and implementation of sustainable transportation. Addis Ababa city profile along with its urban transport structure and developments on sustainable transport system that led the foundation and theoretical background of the work are as well summarized and presented at the end of the chapter.

Chapter 3- Presents the research methodology and materials used for the study. Furthermore, briefly define indicators that were used for the assessment in addition to description of indicator selection process.

Chapter 4- starts with indicator analysis explanation along with their valuation and quantification that are useful in sustainability assessment. Correspondingly discusses research findings based on scale of the identified indicators.

Chapter 5- Concluding remarks and recommendation

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Transport systems are key elements of urban areas; therefore their sustainability has a pivotal role in achieving complex urban sustainability. Nowadays the assessment of urban sustainability is a hotspot in different scientific fields despite of lack of comprehensive and widely accepted definitions of both urban sustainability and sustainable transportation. Consequently, there is growing interest in sustainability, sustainable development, and sustainable transport. The use of divergent indicators for evaluating sustainable urban transportation has emerged as a core of urban studies.

Many papers, reports and books have been published dealing with sustainability issues, and many communities are involved in sustainable planning projects. The nature and scope of these issues, and their implications for transportation planning and policy are only beginning to be explored. This chapter reviews issues related to the definition, evaluation and implementation of sustainable transportation. Addis Ababa city profile along with its urban transport structure and developments on sustainable transport system that led the foundation and theoretical background of the work are also summarized and presented at the end of the chapter.

2.2. Definition of Sustainability and Sustainable Transportation

There is no universally accepted definition of sustainability, sustainable development or sustainable transport. The most common one is that Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland Commission, 1987) and sustainable transportation can be viewed as an expression of sustainable development in the transportation sector.

Sustainability is sometimes defined narrowly and this tends to overlook many relationships between issues and opportunities for coordinated solutions. For example, some climate change emission reduction strategies may exacerbate other economic, social and environmental problems, while other strategies provide multiple benefits (Litman, 2006). A comprehensive analysis can take into account these additional impacts and identify no regrets solutions, which help achieve multiple objectives.

Zegras (2006) emphasized accessibility as the main feature of sustainable transportation and did not provide approaches concerning economic and environmental dimension of sustainability. On the other hand most of the studies regarding sustainable transportation concentrate on the environmental impacts of motorized transportation modes (Török, 2014 and Tóth-Szabó & Várhelyi, 2012). This barrier was mentioned by Litman (2018), who stated that some of the variables and conceptions suggested in different studies reflect to the environmental aspects and decision making processes provide ecologically effective, but economically ineffective. Another indicators reflected to economic situation may result in ecologically ineffective decisions.

Shiau and Liu (2013) cited the definition of transport sustainability provided by European Council of Ministers of Transport which describes the concept with the following features:

- from social side, a sustainable transport system provide basic accessibility of individuals and society, moreover makes connection between present and future generation;
- from economic side, it enhances competitiveness and regional development through affordable and efficient operation;
- Finally from environmental side, it promotes the use of renewable resources and the limit of emissions and waste in terms of planet’s absorption ability; furthermore these features can prevent future negative impact.

Sustainability reflects the fundamental human desire to protect and improve our earth. To avoid unilateral and uncommon definitions, the broadest concept of sustainable transportation may be accepted, as “satisfying current transportation and mobility needs without compromising the ability of future generations to meet their own needs”.

Many experts use a comprehensive definition that sustainable transport must balance between economic, social and environmental goals, called a *triple bottom line*, as illustrated in figure. Although each goal fits into a specific category, they often overlap. For example, pollution is generally considered an environmental issue, but it also affects human health (a social issue).

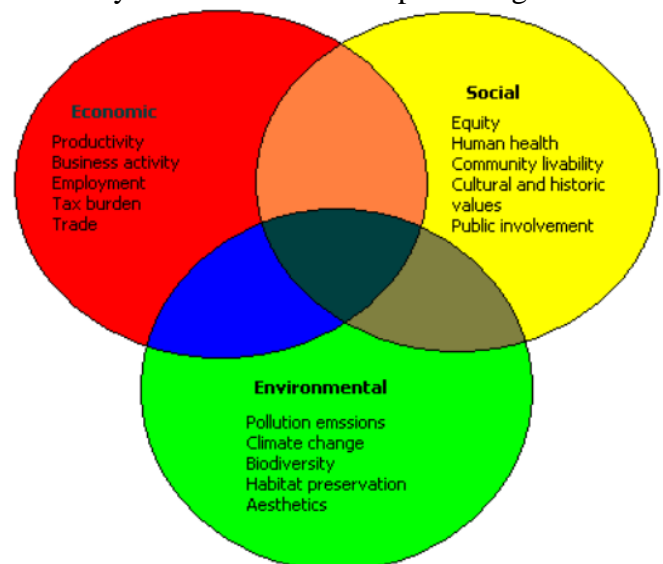


Figure 2-1: Sustainability Goals, Source: Litman, 2018

2.3. Transportation Challenges and Impacts on Sustainability

In many cities of the world, the equation of ‘mobility’ with ‘transportation’ has raised a tendency towards increasing motorization, and a propensity to expand the network of urban roads. Highway structures, including overpasses and flyovers, tunnels and foot-bridges have become standard features of the modern city and urban landscape. Apart from causing a spiral of negative externalities, this approach further distorts the urban form and severely undermines the environmental, social and economic sustainability of cities. The rapid motorization of many of the world’s cities is further compounded by expanding globalization, rising trade flows and incomes, leading to an enhanced demand for personal mobility. In many parts of the world, and particularly in developing countries, the private car has become a status symbol, depicting affluence and success in life. A prime example is the largely unregulated large-scale importation of used vehicles to developing countries. Consequently the transport bias of urban mobility is demonstrated by the dominance of motorization, particularly private motor vehicles being preferred means of mobility and heavy investments in infrastructure.

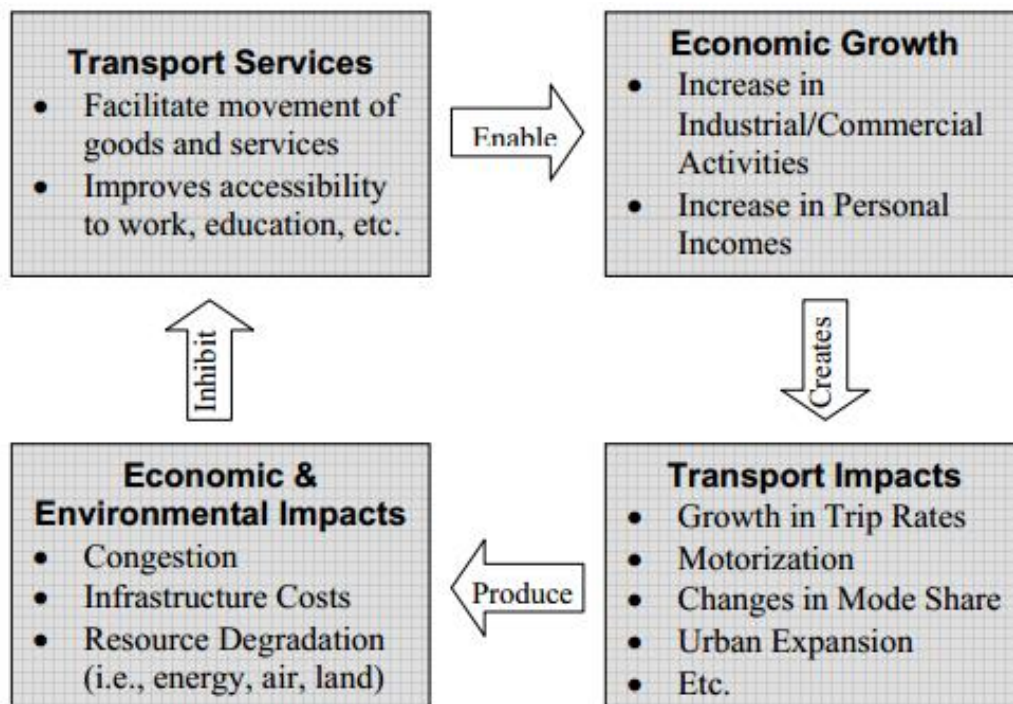


Figure 2-2: The Urban transportation cycle and Sustainability Challenges

Source: Derived from Zegras, 1998

Most of the European cities have to face congestions and air pollution due to individual motorized transport modes (Gössling, 2013) and large part of the population spend hours to reach their destinations, due to constant congestions (Miranda & Rodrigues da Silva, 2012). This is no different for other part of the world, such as African cities, like Addis Ababa. This illustrates the contextual circumstances of urban mobility challenges, which have restricted access to cities by various social groups. Working towards sustainable mobility, renewed efforts within and between governments, are essential in ensuring that solutions are inclusive, participatory, and that all budgetary and resource implications meet the needs of all citizens.

Alonso, Monzón, & Cascajo, (2015) stated that in urban areas, where pollutants and consequently the impacts - generated by unsustainable transport structure - are existing in a concentrated way, the sustainable mobility is a prerequisite of achieving sustainable cities. Shiau and Liu (2013) confirmed these statements, and identified technological change and reduced demand as proper and efficient measures for achieving sustainable transport system. Transportation facilities and activities have significant sustainability impacts in the three dimensions. The sustainability planning does not always require tradeoffs between economic, social and environmental objectives, but rather a matter of finding strategies that help achieve all of these objectives over the long term by increasing transportation system efficiency.

In order to become more sustainable, cities should be more compact, encourage mixed land use and prioritize sustainable modes of mobility such as public and non-motorized transport. Furthermore, urban mobility systems need to be inclusive, providing mobility opportunities for all. Improved urban planning will be critical toward designing and retrofitting cities to better accommodate sustainable modes. Compact, mixed-use cities with high-quality pedestrian and cycling infrastructure, combined with policy measures offer the best hope of increasing the modal shares of sustainable modes of mobility.

A **paradigm shift** is also needed in how transport users think about transportation and its relationship to the city. Of particular significance is the need for government institutions and planning processes to emphasize accessibility over mobility. Furthermore, policies to encourage sustainable urban mobility should take into account social, environmental, economic as well as institutional dimensions of sustainability. This calls for a more holistic and inclusive framework for the planning, design and provision of urban mobility systems and services.

	Old Paradigm	New Paradigm
<i>Definition of Transportation</i>	<i>Mobility</i> (physical travel).	<i>Accessibility</i> (people's overall ability to reach services and activities).
Modes considered	Mainly automobile.	Multimodal: Walking, cycling, public transport, automobile, telecommunications, and delivery services.
Planning objectives	Congestion reduction; roadway cost savings; vehicle cost savings; and reduced crash and emission rates per vehicle-kilometer.	Congestion reduction; road and parking cost savings; consumer savings and affordability; improved access for disadvantaged people; reduced crash, energy consumption and emission rates per capita; improved public fitness and health; strategic land use objectives (reduced sprawl).
Impacts considered	Travel speeds and congestion delays; vehicle operating costs and fares; and crash and emission rates.	A variety of economic, social, and environmental impacts, including indirect impacts.
Performance indicators	Vehicle traffic speeds, roadway level of service, and distance-based crash and emission rates.	Multimodal level of service; multifaceted accessibility modeling, which calculates the time, monetary costs, comfort, safety, security, and environmental impacts required to access services and activities.
Favored transport improvement options	Roadway capacity expansion.	Improve transport options (walking, cycling, public transit, etc.); transportation demand management; pricing reforms; and more accessible land development.
Planning scope	Limited; transport planning is separated from other planning issues.	Integrated and strategic planning; individual, short-term decisions should support strategic, long-term planning goals.
The new paradigm expands the range of modes, objectives, impacts, and options considered in planning.		

Table 2-1: Changing transport planning paradigm

Source: Litman T. , *The New Transportation Planning Paradigm* (2013)

The need to focus on access as the basis for urban mobility planning arises because it became increasingly difficult to access places, activities and services despite the increasing level of urban mobility. This urges planners and decision-makers to move away from a ‘transport bias’ towards a focus on the human right to equitable access to opportunities. Hence designing of sustainable and livable city requires the change of focus from conventional practice of mobility-based road planning to accessibility-based transport planning so that better activity coupling can be achieved through complete street design and mixed use land policies (Toth, 2011; Farr, 2008).

The comparison of old and new paradigm of transport planning (Conventional vs. Sustainable) derived from Litman (2013) is presented in the Table 2-1. It shows that in the former case, the car is the primary focus with limited planning scope while the latter approach strives to strike a modal balance through transport and land use integration and prioritization of PT, walking and cycling. This concepts were also reflected in Bertolini et al (2005) who states that *“A shift of focus in urban transport planning from catering for mobility to catering for accessibility may help see how more sustainable travel options (e.g. walking, cycling, public transport, shorter car trips) can, under certain land use conditions (e.g. higher densities, more finely -tuned functional mix) provides a competitive degree of accessibility that matches less sustainable options”*.

The focus on accessibility emphasizes the need for a holistic and integrated approach to sustainable urban mobility. It establishes a link between urban form (in terms of shape, structure, function as well as demographics) and transportation systems. Particular attention is given to the urban form’s potential to support the increased proximity of places and functions, thus minimizing the need for extended movement. The backbone of accessibility-based urban mobility is public transport, particularly high-capacity PT systems that are well integrated in multimodal arrangement. The bottom line is the quality and efficiency of reaching destinations whose distances are reduced. Equally important is the affordability and inclusiveness in using the provided facilities.

Sustainable mobility can be determined by the degree to which the city as a whole is accessible to all its residents, including low-income earners, the elderly, the young, the disabled, etc. Furthermore, transport interventions should be explicitly targeted to prevent negative outcomes. By giving priority to PT and NMT, the need for private cars is reduced. Strategies to change public attitudes and encourage sustainable forms of mobility thus have a key role to play.

2.4. Implications of Sustainable Transportation

According to Zito and Salvo (2011), the following are necessary for reaching sustainable mobility: decreased demand of transport needs, encouragement of modal shift, decrease of trip length and incentive of more efficiency. Sustainability objectives have several implications for transport planning.

- Sustainable transport planning necessitates paradigm shift, a fundamental change in the way people think about, which helps in *Transportation decision making*. (Litman, 2013)
- Most sustainable transport planning supports *reduced automobile dependency* (defined as high levels of automobile use, automobile-oriented land use, and lack of travel alternatives), which imposes various economic, social and environmental costs (OECD, 1999; Newman and Kenworthy, 1998).
- *Transportation equity* has several potential implications for transport policy. Horizontal equity implies that externalities of transportation should be reduced (reducing pollution emissions, accident risk from motor vehicle use, or compensating those who bear such external costs). It also implies users should ‘get what they pay for and pay for what they get’ whereas Vertical equity implies that access options should improve for people who are economically, socially and physically disadvantaged.
- *Community liveability* includes quality of local environment, community interactions and cohesion and the ability of a community to satisfy the basic needs of residents (such as food, shelter, education and medical services) (Gustavo and Manor, 1998; Putnam, 1993). It can support sustainability objectives, like reducing need to travel and increasing the use of public transit, ridesharing, cycling & walking. Burden (1999) suggests that *Community livability* is important for sustainable development as it offers creating more attractive, interactive, pedestrian-friendly streetscape, and other policies that encourage NMT.
- Transportation patterns can be affected significantly by *land use* patterns (Moore and Throsnes, 1994; Kelly, 1994). In particular, hierarchical street patterns, generous road and parking supply, and automobile-oriented site design tends to increase automobile dependency, leading to high levels of per capita motor vehicle mileage and a reduction in the quality of travel alternatives (transit, walking and cycling).

2.5. How to Measure Sustainability

Nowadays, the significant economic and social changes that are taking place as well as the emergence of environment protection makes the need for sustainable urban mobility planning more and more necessary. Concern about sustainability can be considered a reaction to the tendency in decision making to focus on easy-to-measure goals and impacts, while ignoring those that are more difficult to measure. Sustainable decision making can therefore be described as planning that considers goals and impacts regardless of how difficult they are to measure.

Although sustainability is difficult to be measured directly, it can be evaluated through a system of parameters which reflect its dimensions. Indicators constitute part of this process and since their first establishment in 1992 by the United Nations Conference on Environment and Development they are being increasingly accepted as a tool for the assessment of the sustainable urban mobility mainly due to their simplicity in communicating complex phenomena. Accordingly sustainability is evaluated using a set of measurable indicators to track trends, compare areas and activities, evaluate particular policies and planning options, and set of performance targets (Litman, 2003; CST, 2001).

However, despite the great usage of indicator sets, there are still many issues to be addressed. Which indicators are selected can significantly influence analysis results. A particular policy or program may rank high when evaluated using one set of indicators, but low when ranked by another set. There is a tension between convenience and comprehensiveness when selecting indicators. In specific the large number of indicators makes, in the most of the cases, the evaluation process lengthy and in many occasions unsuccessful due to the absence of relevant data, especially in urban areas lacking organized databases such as Ethiopian cities. As well have unreasonable data collection costs even if larger set could be more comprehensive. Smaller set of indicators, on the other hand, using easily available data is more convenient, simple and easy to use but may overlook important aspects and impacts.

It is also important to avoid confusing goals and objectives when selecting indicators. Goals are what society ultimately wants. Objectives are things that help achieve goals, but are not ends in themselves. Decision makers sometimes focus on easy-to-measure impacts and objectives, while overlooking more-difficult-to-measure impacts and goals.

Conventional transportation quality indicators mostly consider motor vehicles traffic conditions (Litman, 2003). Below are examples:

- roadway level-of-service: a higher rating is considered better
- average traffic speeds: assumes higher is better
- parking convenience and price: increased convenience and lower price is considered better
- Crash rates per vehicle mile: lower crash rates are considered better.

Because they favor motorized travel, these indicators tend to *contradict* sustainable transport objectives. For example, they justify roadway and parking capacity expansion that increases per capita vehicle travel and reduces walking, cycling and public transit use. This increases resource consumption, pollution emissions and land consumption, and exacerbating the transport problems facing non-drivers.

There is a steadily increasing number of international studies analyzing sustainability indicators or creating composite indices to evaluate transport systems in urban areas. According to Attila Buzási and Mária Csete (2014) variability of aims and objectives of different studies cover a broad range from one-dimension analysis to interdisciplinary ones. All in all variables were provided by analyzed studies, some of them are overlapping with each other, but most of them are unique due to the divergent aims of papers. This divergence indicates an important principle regarding urban planning, since features and related challenges vary from cities to cities, thus **unique variables and composite indices** shall be compiled.

Therefore identifying of appropriate performance measures and indicators that are applicable in **own country** and development of an index for sustainable transportation for comparison and decision-making purposes is needed.

Consequently the first part of this work was to review a considerable number of sustainable urban mobility indicators from different literatures, examines the data availability and reliability in Addis Ababa city and finally contends towards a practical, realistic and comprehensive indicator system as an evaluation tool of the mobility conditions. A detail description of the literature used and criteria developed for the selection process can be found in **chapter 3**.

2.6. Addis Ababa City Profile and Its Urban Transport

A general description and an overview of study area that led the foundation and theoretical background of the work are presented here. Addis Ababa which means ‘New Flower’ is the capital city of Ethiopia and is the political, commercial, economic and financial hub of the country. It is also the 4th largest diplomatic center in the world as it is a seat of UN Economic Commission for Africa (UNECA), African Union (AU) and a home of more than 90 embassies and various international organizations. The city is often referred as the “political capital of Africa” due to its historical, diplomatic and political significance for the continent.

Located at the geographical center of the country, it is in continuous process of fast paced urbanization and is a home of around 5 million inhabitants (Demdime, 2012). Addis Ababa lies at average altitude of 2,500 m above sea level and has an expanded area greater than 540 km² experiencing a rapid pace of socio-economic and physical transformation. The city has temperate climate with average minimum and maximum temperature being 10 and 21° C. The city has three hierarchies of administration, Addis Ababa City Government that is run by the City Council being at the top and then divided in to 10 Sub-Cities and 99 smaller administration units called kebeles as second and third layer of administration.



Figure 2-3: Addis Ababa City map

Source: Addis Ababa, Ethiopia: Challenge of urban mobility, Clélie Nallet, 2018

Addis Ababa Urbanization: As we know urbanization in Addis Ababa is rapid and due to its expansion and fast development 100% of the population is considered as urban population. It concentrates 25% of the country's urban population. The process of rapid urbanization has resulted in the increase in the size of the population and the physical expansion of the city. The exponential urbanizing rate is expected to transform it into a megacity of almost 10 million people by 2037. Recent growth has been sprawling with low density, with the rate of spatial expansion outpacing the rate of population growth. This has implications for the cost of infrastructure and service delivery, traffic congestion, land management, social inclusion, and overall liability.

According to Nallet (2018), the growth in the number of inhabitants is combined with a dynamic spatial development of the capital, with a sprawl of the city particularly towards the east and the south. The urban expansion is particularly large towards the southeast where a mixed industrialized and residential area is developing, towards the cities of Debre Zeyit and Nazret. This spread does not occur without political tensions. As Hussen (2017) mentioned although regional towns are becoming increasingly important due to the decentralization and regional development policy of the current government, Addis as a primate city will continue to attract more migrants and will experience a huge growth in its population in the future.

Addis Ababa Urban Population growth: The result of urban growth expanding in a sprawling manner is estimated 46% of vacant or underutilized land. Indeed, the rate of urban sprawl is faster than that of population growth, which is reflected by a very high density in the central districts (around 15,000 to 30,000 inhabitants per kilometer) which concentrates 30% of the population in 8% of the urban area.

Recognizing the strategic importance of Addis Ababa, the government is taking steps to address important urban issues. The rapid population growth in Addis Ababa demands more transport vehicles, more energy from fossil fuels, as a result more emission and greenhouse gases are produced. It also affects environment through their consumptions of food, energy, water and land. The polluted environment in turn affects the health and quality of life of the population. Due to this rapid urbanization energy consumption, transportation, cooking, and heating is much higher in Addis Ababa

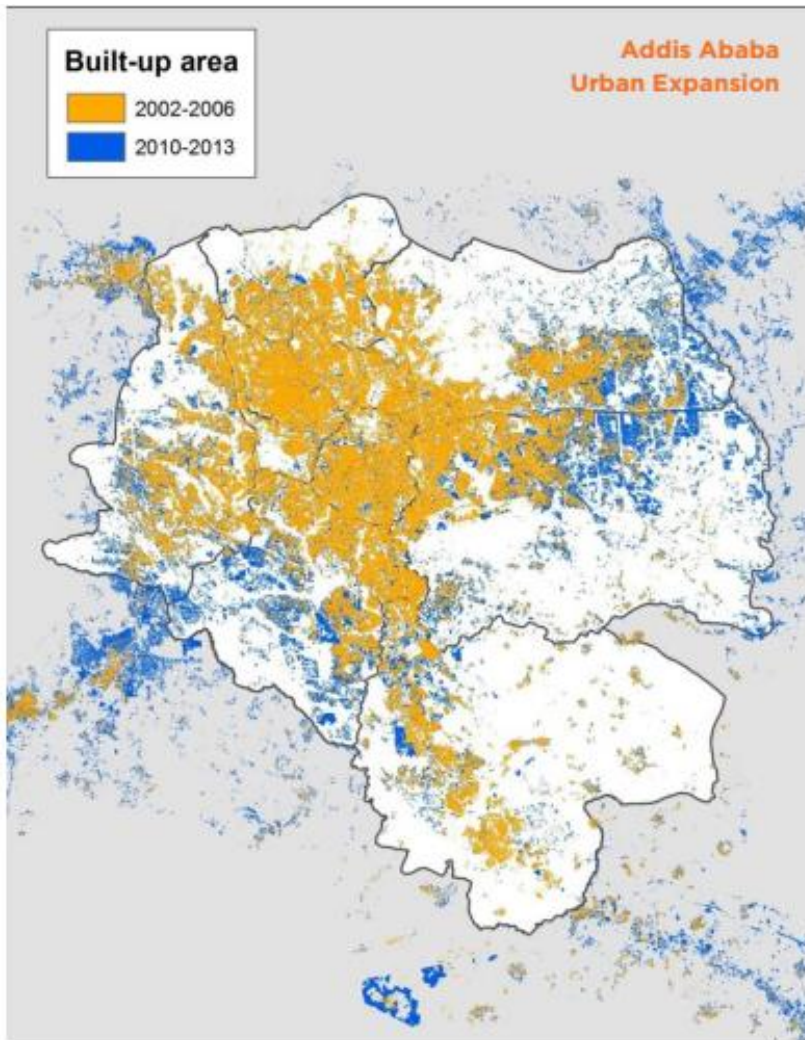


Figure 2-4: Addis Ababa's urban expansion

Source: Addis Ababa, Ethiopia, Enhancing Urban

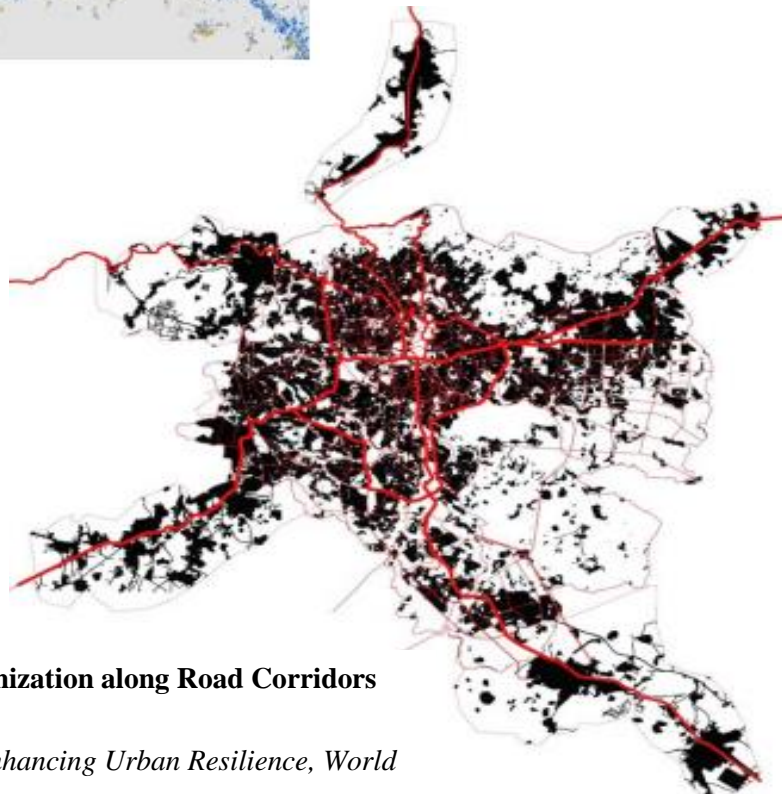


Figure 2-5: Addis Ababa Urbanization along Road Corridors

Source: Addis Ababa, Ethiopia, Enhancing Urban Resilience, World

2.6.1. City Demographics

Addis Ababa Population growth trend: Addis Ababa’s growth was fanned by in-migrations from rural origins starting early in its existence and it began its rise to megacity status between 1967 and 1975 when rural to urban migration in Ethiopia was at its peak. Various estimates put the current population size greater than 3 million. There are projections that this figure will increase to 12 million within 20 years. Among the migrants coming from rural areas, the activity rates of those residing in Addis Ababa are much greater when compared with other cities. This is due to the fact that the majority of economic activities including industry, infrastructures and roads network are concentrated in the capital city than in the other cities.

There is no reliable comprehensive statistical data to show Addis Ababa’s population trends since its establishment. The current population estimate of the city ranges from 3.5 to 5 million inhabitants, depending on who the source is, like UN-HABITANT, World Bank or Central Statistics Agency of Ethiopia (CSA) reports. The CSA’s estimates for the same year even fluctuate among its different sources. The city of Addis Ababa’s current population growth rate is estimated at 3.0% by the CSA and 3.8% by the World Bank (2015). The first census data was obtained only in 1961. However, several researchers have provided estimated population numbers. According to the Central Statistical Authority estimates (Summary and Statistical Report of the 2007 Population and Housing Census Results, statistical report on the 2013 national labor force survey and Ethiopia population projection of Ethiopia for all regions at wereda level from 2014 –2017) history of population in Addis Ababa is summarized as follows:

Table 2-2: Population in Addis Ababa

Source: Central Statistical Agency

Year	Population in Addis Ababa
1,961	443,728
1,967	1,167,315
1,984	1,423,111
1,994	2,112,737
2,007	2,739,551
2,013	3,156,057
2,014	3,195,000
2,015	3,273,000
2,016	3,352,000
2,017	3,433,999

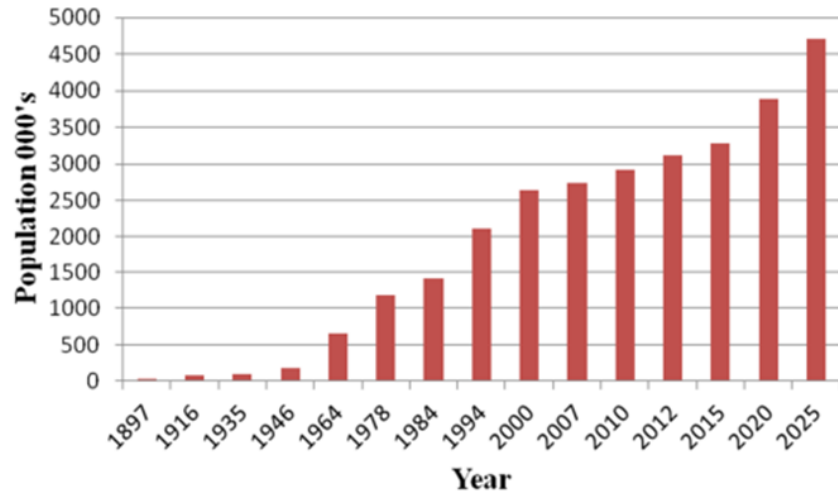


Figure 2-6: Population size of Addis Ababa between 1897 and 2011 and projection to 2025

Source: Abeje, 2000; UNPD, 2012 & Hussen 2017

2.6.2. Socioeconomic Snapshot

Addis, home for 25% of the urban population in Ethiopia, is one of the fastest growing cities in Africa. It has a significant contribution in the economic, social and political sector development as well as the growth engine for the country. It is major pillar in the country’s vision to become a middle-income, carbon-neutral and resilient economy by 2025. Its economy is growing annually by 14%. The city alone currently contributes approximately 50% towards the national GDP, highlighting strategic role within the overall economic development. Based on data from the city administration’s Bureau of Finance and Economic Development (2016), the GDP has grown, on average, by more than 15% over the last five years; much faster than the national GDP.

Table 2-3: Addis Ababa city GDP and per capita income (PCI)

Source: The State of Ethiopian Cities 2017 report’s calculation based on CSA (2015), BoFED (2016) and National Bank of Ethiopia (NBE) (2016).

Year	Population size	City GDP at current price(in ETB millions)	Average PCI (ETB)	Average annual exchange rate	ETB-USD PCI in USD
2011	2,913,745	46,763	16,049	17	931
2012	3,047,000	55,650	18,263	18	1,011
2013	3,103,673	66,264	21,350	18	1,143
2014	3,194,999	78,040	24,425	19	1,257
2015	3,273,001	90,908	27,775	20	1,364

Regardless of the strong economic growth trends, Addis Ababa faces significant development challenges, particularly in terms of ability to supply the population with basic services, access to housing, mobility and health services. The local government is struggling to address it. Owing to its central geographic location, Addis is on the crossroad linking all the corners of Ethiopia. Most goods and services produced in the country end up marketed in Addis Ababa. The city enjoys superior access to ICT services, roads, utilities and other infrastructure compared to the regional capitals. Hence, the economic agglomeration effect is significant as compared to other Ethiopian cities. Agglomeration economies occur where transport infrastructure “clusters” economic activities and connects firms at lower cost. This typically leads to higher productivity. This socio spatial reconfiguration tends to accentuate, rather than solve the inequalities of access to the city, and raises major concerns, particularly that of the risk of social fragmentation. The issue of mobility and access to transport is crucial here. Transport is the engine of urban life that makes the proper functioning social and economic activities possible.

2.6.3. Mobility and Transport System in Addis Ababa

Over the past years as Addis Ababa expands in size and increases in urban population, it has not been provided with an equal growth in urban transport provisions. But the rapid urbanization is necessitating growth in the need of transportation in the city. The transport system offers multiple modes of transport for its users to ensure the continuity of mobility in the event of disruptions and access for all population groups in a city.

2.6.1.1. *Urban Transport Modes, Urban Trips and Modal Share in Addis Ababa*

The choice of a particular mode of urban transport depends on factors such as accessibility, ease of operation availability and quality of respective modes. The dispersion of various urban activities at different locations generates urban trips. The purpose of travel encompasses broad range of life activities such as work trips, school, shopping, recreational and social activities and trips to social services (medical visits and worship center). Globally work and school trips are important trip purposes (Vasconcellos, 2001) and ERA (2005) stated that Addis Ababa’s most important trip purposes is as well “work” and “education” which accounted for about 32 and 46% of all trip purposes respectively. Demdime (2012) and Nallet (2018) also confirmed work and education are the dominant purposes of urban trips in Addis Ababa.

As Hussen (2017), cited the daily temporal patterns of trips reflect the double peaking characters of school and work trips. Most offices and school open at the same time in the morning but in the afternoon schools close earlier than offices. In response, there is one major peak in the morning and two minor ones in the afternoon. Most of the trips (about 36 %) occur in the morning peak hours of 6-9 a.m. NMT (predominantly walking) and collective informal sectors (minibuses and taxis) are the dominant means of transport that account for 35 to 40 % of urban trips across the whole continent of Africa (UITP and UATP, 2010).

2.6.1.2. Urban Transport Service Provision and Travel Cost

The urban transport service provision in the city of Addis Ababa has been greatly relying on limited number of city buses (535 of which only 325 are operating) (UITP and UATP, 2010) and around 12,000 privately operated blue minibuses (Meron, 2007) and 495 midi buses. The city bus and minibus have carrying capacity of 100 (30 seated and 70 standing) and 12 passengers respectively. Midibuses, which carry 25 passengers, have limited share in the urban transport and operate in the same manner as minibuses-on the basis of full dispatch load.

Public transport is provided by the governmental Anbessa city bus enterprise and thousands of private operators of minibus taxi, midibuses, saloon taxis and three-wheelers or Bajajas. Addis Ababa Transport Branch Office (2012) estimated that about 18,000 public transport vehicles are daily operational in the city, with 12 seater-minibus taxis and saloon taxis accounting for about 90% of the total fleet. With a low density of the road infrastructure (13% of the total area), the great number of low capacity public transport vehicles puts further pressure on the congestion prone major corridors of the city.

The urban transport study shows that both the trip length and mobility rates are on the increase (ERA, 2005). Mobility rate in 2005 was 1.07 trips/persons/day generating 3.35 million trips per day and is estimated to increase to 1.4 trips/person/day and thereby producing 7.7 million person trips per day in 2020. The share of motorized trip rate from the total mobility is projected to rise from 0.43 in 2005 to 0.7 trips/person/day in 2020. Even if slightly declining, walking is still the most important mode transport in the city. Addis Ababa currently manifests low motorization rates by global standards but the rapid economic growth in recent years is expected to lead to a strong increase in vehicle ownership.

Travel cost of motorized modes is rising following the increase in international fuel prices. Public transport fares have increased by over three fold since 2008. There is no data to determine how much people really spent on transport and the relationship between income levels and transport expenditures. Above all there is no study on how do people, particular the poor living at the city peripheries where house rent is comparatively lower and there is easier access to own houses in the informal housing sector, adjust to increasing costs of living relative to income not rising as proportionally as the costs of living.

Pedestrians remain the most poorly served of travelers, with more than 65 percent of the road network lacking pedestrian walkways, even though studies estimated walking accounted for greater percent of all trips. Sidewalks, where they exist, are often obstructed with parking, utility installations or other discontinuities; busy arterials, even those designed and built within the last few years, have few and poorly designed pedestrian crossings. As a result, pedestrians, who tend to be poor, bear a disproportionate share of the burden from road traffic crashes; statistics from the Federal Road Transport Authority show that 60 percent of all serious crashes and 73 percent of all road traffic crash-related fatalities affect pedestrians.

2.6.1.3. *Transport Challenges and Solutions Applied*

Addis Ababa has grown faster than the supply of transportation in terms of transportation infrastructure and public transportation. The mismatch between the demand and supply in the city is manifested by the shortage of public transportation, low road density and availability, chronic traffic congestion and travel delays and misuse of the road space. The demand for transportation services and infrastructure, as derived demand, is strongly linked with urban activity systems that are expressed in different urban land uses (ERA, 2005; Hussen, 2017).

Nallet (2018) also discuss how land use and transport developments are poorly coordinated. Housing and land-use decisions are taken on the basis of the location of available land, with almost no assessment of transport impacts while road transport investment decisions are made on the basis of criteria often unrelated to land-use patterns. For example, new condominium housing has been developed on the (current) outskirts of the metropolitan area, with no coordination with transport services, rendering them largely inaccessible not only to employment locations, but also to social services and interaction.

In his study of models relating traffic safety with road environment and traffic flows on arterial roads in Addis Ababa, Birhanu (2003) concluded that the traffic management system in Addis Ababa, unlike many modern cities, is growing without adequate plan and control, which led to the existing mixed-up land uses. He labeled the city's **road networks** inadequately planned to meet the traffic demand. Road hierarchies are not well established and arterial roads are not access controlled. He also states that the traffic management system in the city is inadequate to cope with the rapidly increasing motor and pedestrian traffic. Traffic controls, signs, and markings as well as pedestrian facilities are not in place. The rapidly increasing traffic on the undeveloped road infrastructure coupled with the unsafe behavior of road users results in a highly conflicting traffic that consequently leads to the occurrence of many road accidents in the city.

Over the past few years, Addis Ababa has been making a concerted effort to improve the urban transport situation, largely through large investments in new infrastructure, including roads, LRT system and plans for a new BRT system, and improved standards and practices for improving and integrating pedestrian facilities in major transport capital projects. But the city's approach to address urban transport problems over the past twenty years— predominantly by expanding the transport infrastructure —has not made the desired improvements in accessibility for pedestrians and many public transport users. Daily time spent traveling in the city has increased and the city faces high levels of road traffic accidents, frequent congestion, and high levels of air pollution. These challenges are manifest even though motorization in Addis is quite low by world standards. Investments in expansion of the road network have not been accompanied by improvements in traffic management or the development of public transport services.

Overall, here are some **summarized issues about road mobility** in the city of Addis Ababa.

- **Infrastructure provision:** Until the mid of 2015 all passenger and freight mobility in the city was ensured through roads. It was only recently that a Light Rail Transport (LRT) for passenger transport began construction (in 2011) and was opened for public use on November 2015. Though massive road construction and improvement works have been going on in the city and has contributed to the efficiency of transport mobility has changed the image of the city as well as facilitated other socio-economic developments, there is a huge work to be done in the road infrastructure as a whole.

- **Class and quality of roads** have great influences on the efficient and effective mobility of vehicles in the road transportation system. The **widths** of the roads in Addis Ababa are claimed to be not sufficient for the daily commuting 180,000 vehicles in the city (Asegid, 2010). Road **quality** in Addis Ababa is labeled as poor and insufficient for the mobility of the road traffic that it accommodates; for which, the major reason is the frequent deterioration of both the constructed and rehabilitated roads due to surface and pavement drainage systems.
- **Operation of vehicle:** Impediment of the traffic flow due to insufficient widths and poor quality of roads affects the operation modes of vehicles. The idling creates unnecessary fuel consumption of the vehicle which then will increase the potential of exhaust emission from vehicles.
- **Vehicle Ownership** is low in Addis Ababa (below 100 vehicles per 1000 of population), though rapidly increasing mainly due to economic growth and the introduction of low cost private cars into the local market (Yared, 2010). There are about 403,711 vehicles with an annual average growth rate of 10% .More than 70% of registered vehicles in the country are found in Addis Ababa (The transport policy of Addis Ababa).
- **Vehicle Age:** most of them are old more than 15 years of age (Tsehaynesh, 2010). According to the Road Transport Authority of Addis Ababa (2013) of the registered freight vehicles in the city 55% of them have an age more than 10 years. The **engine efficiency of vehicles decrease as the vehicle ages** which affects the combustion processes of vehicles and therefore exhausts emissions.
- **Behavior of drivers:** The other major important factor in the road mobility in the city of Addis Ababa is the behavior of drivers. The driving norm in the city of Addis Ababa can be labeled as *chaotic*. There could possibly be many interrelated factors that could be a reason for the observable problem. Among the many factors, the non-existence of stringent laws and also enforcement of these laws can be taken as the very root causes for the problem.

CHAPTER 3: RESEARCH APPROACH AND METHODOLOGY

This research explores the sustainability of urban mobility, focusing on the need for assessing and evaluating sustainable transport system and traffic growth in response to the transportation challenges and problems faced in Addis Ababa. These issues are identified as major priorities in most of the national and local strategies and policy documents in Ethiopia and a number of policies are formulated. But the practical picture of the city is getting even worse as each and every land development in the suburbs of the city creates an enormous pressure on the transport infrastructure as a result of not being provided with equal growth in public transport services.

Measures which differ from the ones with the conventional focus of congestion and mobility should be assessed to quantify sustainable transportation. This required a study on the trends of transport service provision as well as traffic growth and its effect on development of sustainable city. In addition, major problem area and priority of improvement in realizing sustainability goals for the city of Addis Ababa are explored from different literatures and are coupled with evaluation in order to address the aims of the research.

The next figure shows the theoretical path from the “sustainable urban mobility” concept to a visualization of its outcome that was used as principal guideline of thesis work.

- It starts by identifying the dimensions and the selection of a set of indicators that describe sustainable mobility in cities in a comprehensive way. The *selection* includes finding out how to parameterize each of the indicators: i.e. defining how to quantify them (selecting a unit of measurement for the parameter and composing a formula to calculate it).
- The next step is to *measure* and *calculate* the indicator values.
- After calculating the indicator values, they need to be *standardized into scores* based on a standardized scale.
- Finally, they can be presented in a spider chart, offering a radar view of sustainable urban mobility performance.

Sustainable mobility indicators help to disaggregate the complex system of mobility in cities. The indicators are well distributed among the different sub-dimensions of sustainability. Detail methodological approaches followed for each steps are presented in the subsequent sub chapters.

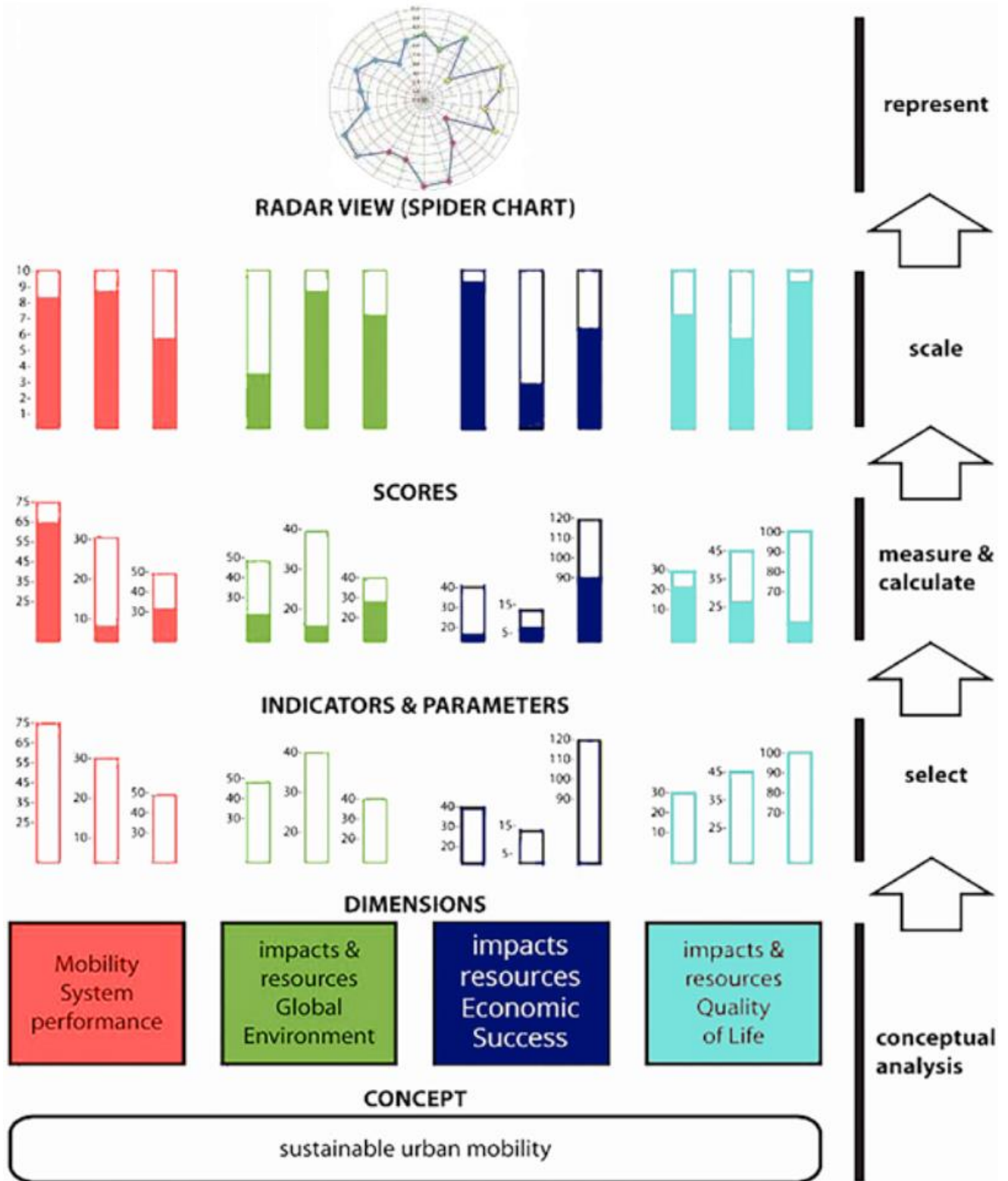


Figure 3-1: Theoretical path from concept to spider diagram

Source: Oran Consulting for WBCSD SMP 2.0, 213, partly based on Boulanger, P.M., 2008

3.1. Methodology for Indicator selection

There is currently no standard set of sustainable transportation indicators. The selection of the right indicators to guide sustainable transport assessment presents two fundamental challenges (Castillo & Pitfield, 2010). Firstly, selecting a subset from a large number of potential indicators exist can be difficult. Secondly, indicators are only abstractions of the system – designed to tell a partial story. Selecting a suite of indicators that provides a holistic picture of system performance is therefore challenging. To come across this challenge a framework for identifying and selecting a small subset of sustainable transport indicators was developed after conceptual analysis.

3.1.1. Framework for Identification of Potential Indicators

As discussed no single measure is a sustainability measure but a set of measures is required. The following procedural framework with clearly defined processes was developed to address the issues mentioned and select *potential local indicators* for the current work.

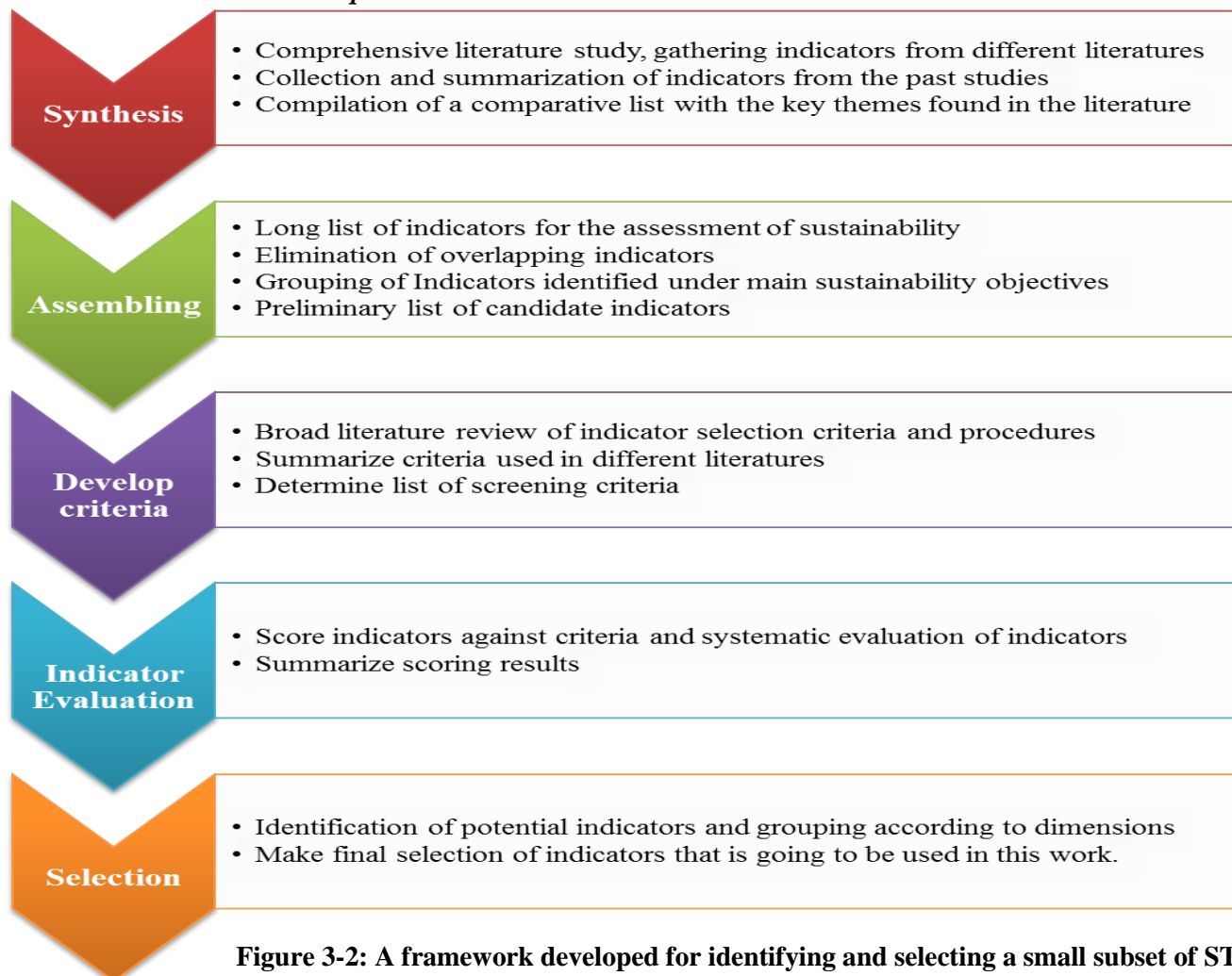


Figure 3-2: A framework developed for identifying and selecting a small subset of STI

3.1.2. Theoretical Study for Identification and Selection of Indicators

Despite the great usage of indicator sets, there are still many issues to be addressed. In specific the large number of indicators makes, in the most of the cases, the evaluation process expensive, lengthy and in many occasions unsuccessful due to the absence of relevant data, especially in urban areas lacking organized databases such as Ethiopian cities. Smaller sets on the other hand may be simple and easy but may overlook important aspects and impacts.

Therefore, the first part of this work was to review a considerable number of sustainable urban mobility indicators from different literatures, examines the data availability and reliability in Addis Ababa city and finally contends towards a practical, realistic and comprehensive indicator system as an evaluation tool of the mobility conditions.

3.1.1.1. Step 1- Synthesis

The selection of appropriate sustainability indicators presents a number of challenges however, not least because of the vast number of potential indicators available. After going through several literatures (Castillo & Pitfield, 2010; Litman & Burwell, Issues in Sustainable Transportation, 2006; Haghshenas & Vaziri, 2012; Litman T. , 2018; Cavalcanti, Limont, Dziedzic, & Fernandes, Sustainability assessment methodology of urban mobility projects, 2017; Rodrigues da Silva, Costa, & Ramos, 2010), a number of journals and international papers were chosen in preference for selecting the initial listing of sustainability indicators.

Table 3-1 below shows sources and number of indicator used into the preliminary long listing. These 13 studies list urban sustainable transportation indicator. In some cases, STI were used and selected from urban sustainable development indicator set. In this step, indicators from the past studies were collected and summarized. These sources were found to be rich and relevant in fields of sustainable urban mobility and sustainable transportation; and are also composed of different scales (spatial level), focus and applicability. Table 3-2 summarizes the studied and reviewed sources that were used for long listing in terms of these parameters.

Table 3-1: Sources and number of Indicators entered into the initial long list

Source	# of Indicators
Modeling for sustainable cities: the transport sector (Kupiszewska,D. 1997)	32
Indicators for the integration of environmental concerns into transport policies (OECD, 1999)	31
Indicators of transport and environment integration TERM (European Environmental Agency, 2002)	38
Indicators to Asses sustainability of Transport Activities(Dobranskyte-Niskota et al. 2007)	55
Recommended research program for developing STI and data (Litman, T. ,2008)	30
ELASTIC A methodological framework for identifying and selecting sustainable transport indicators(Castillo, H. & Pitfield D.E. , 2010)	15
Urban sustainable transportation indicators for global comparison (Haghshenas & Vaziri, 2012)	9
The Future of Urban Mobility 2.0 Imperatives to shape extended mobility ecosystems of tomorrow (A.D. Little, 2017)	22
Guidelines on Developing Performance Metrics for Evaluating Transportation Sustainability (Zheng, J. et al.,2013)	19
Sustainability Indicators in Assessing Urban Transport Systems(Buzási & Csete, 2015)	44
Methodology and Indicator Calculation Method for Sustainable Urban Mobility(WBCSD, 2016)	19
Sustainability assessment methodology on urban mobility projects (Cavalcanti et al. ,2017)	19
Developing indicators for sustainable and livable transport planning (Litman, T., 2018)	20
Total Number of Indicators	353

Table 3-2: Summary of the reviewed sources in terms of different parameters

Authors	Year	Type	Scale/Spatial level	Scope	Focus	Applied	# Indicators
Kupiszewska	1997	Indicator system	Urban	All pillars	Modeling/ Academic	Europe	32
OECD	1999	Indicator system	National level	Env.	Comparative	World	31
EEA	2002	Indicator system	Some at National level & EU level	Env.	Comparative / internal	Europe	38
Dobranskyte-Niskota et al	2007	Indicator system	General	All pillars	Academic	World wide	55
Litman	2008	Indicator system	Urban	All pillars	Academic	World wide	30
Castillo & Pitfield	2010	Indicator system/Index	Urban	All pillars	Academic	UK	15
Haghshenas & Vaziri	2012	Index	Urban	All pillars	Comparative	World wide	9
Zheng et al.	2013	Index	National & Regional	All pillars	Comparative	US	22
A.D. Little	2014	Index	Urban	All pillars	Comparative	World	19
Buzási & Csete	2015	Indicator system	Urban	All pillars	Academic	Hungary	44
WBCSD	2016	Indicator system	Urban	All pillars	Internal	World wide	19
Cavalcanti	2017	Indicator system	Urban Mobility Projects	All pillars	Academic/ Institutional	Brazil	19
Litman	2018	Indicator	General	All pillars	Academic	World Us	20

3.1.1.2. Step 2: Assembling and Developing a candidate indicators

Assembling a long list of indicators identified from literatures for the assessment of sustainability was the next step. Total of 353 individual indicators were found which most are overlapping so a general organization technique was developed so as to short list into 70 most relevant indicators grouped under different major sustainability objectives. A procedure was developed for grouping and identifying overlapping indicators using a spreadsheet. The analysis of categorizing and merging coinciding indicators was done after an extensive literature review.

3.1.1.3. Step 3: Developing Screening criteria for evaluating indicators

At first a broad literature review of indicator selection **criteria** and procedures was done. There are approximately similar types of criteria specified across areas, including sustainability of transportation but no uniform idea were found about how to categorize criteria (i.e. what does a particular criterion help to accomplish?) Lacking this and many overlaps **with limited guidance** on how to select, and apply criteria make the screening process a bit hard.

As many experts and researchers would agree sustainability in transportation is difficult to measure, indicators are necessary tools to monitor and manage it. There are numerous potential indicators of varying relevance and quality; Given a set of potential sustainable transport indicators, one should seek to identify a subset comprised of as small as possible number of sustainable transport indicators that would be most appropriate for assessing the sustainability performance of a given transport system. Therefore, **Criteria** for selection of indicators are needed. The specific indicators that are most important will depend on the particular context and application.

A. Indicator selection criteria from different literatures

Different literatures (Hart, 2006; Litman, 2012; MacDonald, 2000; Malkina-Pykh, 2002; Patrick, 2002 ; Zheng, Garrick, Atkinson-Palombo, McCahill, & Marshall, 2013) extracted a core set of criteria that can be used which includes *relevance to sustainability, policy relevance, understandable and useable, clear in content and transparent in structure, appropriate to scale and technically measurable and feasible.*

The report of Canadian Victoria Transport Policy Institute (VTPI) prepared by Litman T. (2007) also suggests the best practices for selecting indicators to measure transportation performance take into the account of *comprehensiveness, data quality, comparability, easiness to understand, accessibility and transparency*. These criteria are also acceptable in several past studies including Dobranskyte-Niskota, Perujo, & Pregl (2007); Joumard and Gudmundsson, 2010, Haghshenas & Vaziri, (2012). They also highlight the significance of indicator quality selection criteria as these help to reflect important characteristics.

Hangshenas & Vaziri (2012) collected requirements for indicators from different international studies. According to the collection, **effective and useful indicators are:** easily understandable, reasonable, measurable, possible to quantify, accessible, comprehensive, reflect various aspect of study, sensitive to changes over time, independent, standardized for comparison, clearly defined and capture long-term processes. According to Tóth-Szabó and Várhelyi (2012) indicators have **three main functions:** simplification, quantification and communication.

Joumard et al. (2011) determined criteria for indicator assessment and selection as well.

- From measuring point of view, indicators should be valid, reliable and sensitive for the important changes.
- Based on the monitoring function, measurability, data availability and ethical concerns have been identified.
- From the management point of view, selected indicators shall be transparent, interpretable, relevant and actionable. These latter considerations are highly relevant in terms of institutional aspect of urban transport sustainability, which approach was undervalued in the past.

Other important considerations are provided by Litman (2009) regarding indicator selection, namely the cost and the quality of the variables. These are highly relevant, because as Haghshenas and Vaziri (2012) mentioned, the lack of databases is one of the biggest difficulty concerning assessing urban transport sustainability. Inter alia Nicolas et al. (2003), Joumard et al. (2011), Gudmundsson (2003), Alonso et al. (2014), and Miranda and da Silva (2012) mentioned barriers regarding data availability. Finally, Gudmundsson (2003) summarized problems related to measurement of complex features of transport sustainability through environmental, economic and social considerations taken into account in a comprehensive analysis.

In general, indicator quality criteria reflected in the policy documents of the international organizations commonly state that indicators must be clear and understandable, policy relevant, accessible, and reliable and the indicator data must be accurate. Timeliness is an important indicator quality criterion for the EU, Eurostat, EEA and OECD. Cost efficiency of indicators plays an important role for the OECD and UN indicator selections.

Other indicator quality criteria of the organizations reveal their individual differences in focus. For example, ethical value and usefulness of indicators are important criteria for the selection of WHO indicators. The EU considers balancing across different dimensions and mutual consistency within an indicator theme as important quality aspects. The EEA states that progress towards targets should be methodologically well founded and the UN organization outlines that indicators should be within the capability of national governments to develop.

As Buzási & Csete (2015) argues indicators can be quantitative or qualitative; they can be used to assess the reality in absolute or relative way. But quantitative criteria for the development of indicators are also of significant importance according to Dobranskyte-Niskota, Perujo, & Pregl (2007) and Litman T. , (2018). Some quantitative targets established by various recognized institutions may serve as criteria for the development of sustainability indicators. Quantitative targets focusing on the environmentally sustainable transport have been proposed by the OECD (1999). In addition, the EU Sustainable Development Strategy (SDS) proposed certain quantitative policy targets related to transport theme which may help to focus on the priority aspects while developing a set of indicators.

B. Screening criteria used for this work

As said above, there is currently no standard set of sustainable transportation indicators. A variety of indicators are used, some of which are believe to be particularly appropriate and useful for planning and policy analysis. This can include some indicators suitable for all situations, and others for specific needs and conditions. There is no an ultimate or exhaustive list of useful indicators; nevertheless, considering the recommendations from different literatures the following criteria were defined and used to make final selection from the developed list of candidate indicators. The scope of work was also among the criteria to filter the potential indicators of this work.

Table 3-3: Screening criteria for indicator assessment and their description

No	Criteria	Description
1	Target relevance	Each indicator must show one aspect of sustainable transportation
2	Validity	Indicators must actually measure the issue it is supposed to measure
3	Measurability	A sustainable transport indicator should be capable of being measured in a theoretically sound, dependable and easily understood manner.
4	Ease of availability	It should be possible to easily and at a reasonable cost, collect reliable data on the indicator or calculate/forecast the value of the indicator using accepted models.
5	Understandable and Useful	Indicators should be understandable to the general public and useful to decision-makers. The usefulness and value of individual indicators may vary in importance among project phases, jurisdictions, and stakeholders.
6	Interpretability	An indicator and its calculation should yield clear, unambiguous information that can be easily understood.
7	Independent/Transport's impact isolatable	Indicator should be independent of each other's. It should be possible to isolate transport's share of the impact that the indicator is purporting to measure.
8	Level of analysis	If possible, indicators should reflect ultimate impacts of concern rather than intermediary effects. Care is needed to account for possible double counting of impacts, for example, if indicators include both vehicle fuel efficiency and climate change emissions.

3.1.1.4. Step 4: Sets of Selection Criteria and Their evaluation method

These screen criteria are too broad to guide the evaluation of indicators and perhaps some are overlying to some extent. Each criterion is therefore condenses into three sets that the indicators are eventually evaluated. The first evaluation process was limited by the scope of work followed by methodological quality and relevance to transport.

A. Scope of work

In order to efficiently measure and evaluate sustainability performance of transport activities it is essential to define the field of measurement. As noted by Litman (2007), the specific indicators that are most important will depend on the particular **context and application of a given study**. Therefore, scope of the work was among the first criterion that was developed for filtering the finalized indicators.

Scope and limits/bounds used for indicator selection includes:

- a. Particular attention is given to **road transport**, which is responsible for much of the transport sector's impact on the environment. Other modes are also covered (e.g. railway), but are not the focus. Air transport is excluded and the sustainability aspects of these modes are beyond the scope this study. None of the indicators that are going to be used for this research work are necessarily final or exhaustive in character.
- Secondly, isolating the evaluated systems, i.e. distinguishing urban transportation from larger transportation systems or separation of person-transport system from freight transportation as suggested by Zegras (2006), Buzási & Csete (2015) and Zito & Salvo (2011), this study stress on **urban transportation** and **passenger transport**.
- As Buzási & Csete (2015) argues indicators can be quantitative or qualitative; they can be used to assess the reality in absolute or relative way. But quantitative criteria for the development of indicators are also of significant importance according to Dobranskyte-Niskota, Perujo, & Pregl (2007) and Litman T.(2018). Since **qualitative data** are easier to analyze and are often considered as objective than qualitative tend to receive more weight in this study.

B. Methodological quality of the indicators

In breaking down the methodological quality set, measurability and analytical soundness were considered as described below.

- **Measurability** taking into account of:
 - i. **Data availability or readily produced:** Definition and concept available in existing reports, or data should be possible to easily and at a reasonable cost, collect reliable data on the indicator or calculate/forecast the value of the indicator using accepted models.
 - ii. **Data Quality**
 - iii. **Data validity and independency:** measure the issue it is supposed to measure and possibility to isolate transport's share of the impact that the indicator is purporting to measure.
- **Analytical soundness:** theoretical and scientific foundation of indicator taking into account of *understandability* to the general public , *usefulness* to decision-making and Indicator calculation yields *clear interpretation* possible

C. Sustainable Transport framework

Each indicator must show one aspect of sustainable transportation. Policy relevance considers the utility of the indicators to the users. The *relevance of indicators to the concept of sustainable transport* refer to an indicator’s relevance for sustainable development, its relevance to solving problems related to urban mobility, transportation and environmental policy.

Selection Criteria Evaluation scale and method: As said, the first evaluation process was limited by the scope of work followed by methodological quality and relevance to transport. Indicators are reviewed according to the criteria identified as stated, and the evaluation scale according to these criteria is given in subsequent table.

Table 3-4: Selection criteria and evaluation scale developed for analysis of indicators, partially taken from OECD (1999), Rodrigues da Silva, Costa, & Ramos, (2010) and Litman, T. (2008)

Selection criteria	Evaluation		
	1	2	3
Methodological Quality			
<ul style="list-style-type: none"> • Measurability, taking into account: <ul style="list-style-type: none"> ○ Data availability ○ Data quality ○ Data validity and independency • Analytical soundness 	Available/Easy	Medium	Limited/hard; require special data collection
	Good	Average	Poor
	Good	Average	Poor
	Good	Average	Poor
Relevance to sustainable transport	High	Medium	Low

3.1.1.5. Step 5: Analysis and Final selection on the suite of indicators

In summary, **353** indicators were in the preliminary/ initial long list using the 13 sources described in table 3-1 and 3-2. The procedure followed for grouping and identified overlapping indicators as well as categorizing and merging these coinciding indicators to full list of 70 suggested indicators can be seen in the annex (process 2, 2.1, 2.2.). These **70** candidate indicators were filtered by scope first and then evaluated using scale system provided in table 3-4. The scores for methodological quality and relevance indicators for last selection are presented in the annex (process 3, 3.2.). After evaluation a final suite of indicators were developed, that were adjusted/edited and refined to **19** sustainability indicators grouped according to their connection with environmental, social, and economic aspects. Therefore, the report proposes a set of indicators with a sound basis after a process of intensive work and with a basic selection process from different theoretical and conceptual background involved in urban mobility.

3.1.3. Overview of the indicators selected

A set of 19 indicators has been identified to comprehensively describe sustainable mobility and allow assessment of the performance of the city. The indicators may have impact on two or even on the three sustainability dimensions. Summary of the final set of selected indicators and the main dimensions associated with each indicator are presented in table below. The description and objectives related is also offered in the table.

Table 3-5: Final Indicator Selected

Indicators	Description	Objectives
Social		
1. Road Serviceability	Road network length per population	Effective traffic management
2. Accessibility for all/Equity	Accessibility of mobility-impaired groups	Improved access to services and goods
3. Access/PT Network coverage	Share of population with appropriate access to mobility services	Improved access to services and goods
4. Traffic safety	Fatalities caused by urban transport per population	Increased road safety
5. Availability of Public Transport	PT size per population	Promotion of public transportation
6. Opportunity for active mobility	Length of cycling and walking paths per population	Improved access to services and goods/Promotion of NMT
7. PT density per population	PT network length per population	Promotion of public transportation
Environmental		
1. Road Availability/Network Density	Road network length per land take/surface	Effective traffic management
2. Pedestrian infrastructure density	Sidewalks length per km ² of surface area	Encouragement of alternative modes of transport
3. Cycling infrastructure density	Cycle-route network as a proportion of total road network	Encouragement of alternative modes of transport
4. PT infrastructure density	PT network length per surface area	Encouragement of alternative modes of transport
5. GHG	Emissions of greenhouse gases	Reduction of fuel consumption and emissions
6. Age of vehicle fleet	Average age of vehicles	Reduction of fuel consumption and emissions
7. Engine technology of PT fleet	Proportion of PT vehicle fleet meeting certain air emission standards	Reduction of fuel consumption and emissions
Economic		
1. Share of PT	PT as an average share of modal distribution of traffic	Increased multimodality/ Increase transport system efficiency
2. Vehicle Ownership	Number of owned private vehicles per population	Improved access to services and goods
3. Public Finance	Net public finance	Improved access to services and goods
4. Affordability	Affordability of public transport for the poorest group	Encouragement of alternative modes of transport
5. Mobility space usage	Area of direct and indirect mobility space usage per capita.	Improved access to services and goods

3.2. Data Sources and Collection

Different methods of data collection can be used for investigating the different dimensions of the research objective. Data used can be categorized as primary and secondary data. Data were collected using different techniques at various stages. Due to the absence of reliable data sources, a combination of following techniques was employed for the collection of data for city of Addis Ababa.

- **Desktop process and Document analysis:** Going through the existing relevant documents or literatures that are useful for analysing issues related with the sustainability evaluation (Annals /historical record study/, Reports and Web based data collection from official statistical databases)
- **Use of survey methodology:** Use of unprocessed data from previous surveys with the intention of generating required input variables for parameter formulas to fit the sustainability indicator analysis
- **Use of further on Analysis Methodology:** Acquisition of processed data from analysis of geographical information system and extraction of necessary processed data from spatial studies
- **Discussion:** applying the method of dramaturgy (conversation with persons found in concerned governmental bodies without creating the feeling that they are being interviewed) intended for indicator selection and to understand how relevance sustainability evaluation is.
- **Observations:** As a resident and researcher in the city, it was convenient to use the technique of participant-observation for purpose of giving priority for major concerns. By observing the current traffic combination and movement in the city and assessing the transport planning for the city an advantage of directness, diversity, flexibility, and provision of significant attention and applicability was gained as tried to be achieved.

The report uses data provided by government offices like AACRA, Transport office, Traffic police commission and different national agencies. A detailed description of data type and sources used are presented in the following table as well as in the indicator explanation section, which deals with the methodology and scaling of each of the indicators separately.

Table 3-6: Input Data Type and Sources

List of Indicators	Input Data Type and Sources Used for the Study
Social	
1. Road Serviceability	Using existing databases (from AACRA, CSA)
2. Accessibility for all/Equity	Necessary raw/unprocessed data from surveying that was conducted in previous research were extracted for parameter calculation-----Henok Tesfaye,(2014) and Rahel A.Tilahun, (2017),
3. Access/PT Network coverage	Necessary processed data from spatial data analysis by Aklilu & Necha (2018) were extracted for parameter calculation
4. Traffic safety	Using existing databases (from Addis Ababa Traffic Police Office and Addis Ababa Traffic Management agency)
5. Availability of Public Transport	Using existing databases (from Addis Ababa Transport Office and CSA)
6. Opportunity for active mobility	Needed processed data from AACRA’s spatial data analysis were taken for parameter calculation
7. PT density per population	Necessary processed data from spatial data analysis from AACRA extracted for parameter calculation
Environmental	
1. Road Availability/Network Density	Needed processed data from AACRA’s spatial data analysis were taken
2. Pedestrian infrastructure density	Extraction of required processed data from spatial data analysis from AACRA for parameter calculation
3. Cycling infrastructure density	Extraction of required processed data from AACRA’s spatial data analysis for parameter calculation
4. PT infrastructure density	Extraction of required processed data from spatial data analysis from AACRA for parameter calculation
5. GHG	Using existing databases (Addis Ababa city Administration. Addis Ababa Greenhouse gas emission inventory) and document analysis of previous studies.
6. Age of vehicle fleet	Using existing databases (Addis Ababa transport office) and document analysis of previous studies
7. Engine technology of PT fleet	Calculation using existing database(Addis Ababa transport office) as well as document analysis of previous studies
Economic	
1. Share of PT	Addis Ababa road and Transport Bureau: Drivers and vehicle licensing and monitoring Authority
2. Vehicle Ownership	Using existing database (Addis Ababa road and Transport Bureau: Drivers and vehicle licensing and monitoring Authority)
3. Public Finance	Using existing database as well as document analysis of previous studies
4. Affordability	Addis Ababa road and Transport Bureau: Public and Freight transport Authority, Addis Ababa city Administration
5. Mobility space usage	Necessary processed data from spatial data analysis from AACRA extracted for parameter calculation

3.3. Variables and Indicators

There are different types of variables that were used in the study. According to WBCSD (2016), there are seven types of variables:

1. **Common input variable:** these input are variables, such as the number of inhabitants of the city that are used in different indicator parameter calculations
2. **Indicator-specific input variable:** these variables are used in a formula for one of the indicators, for example number of fatalities to calculate the level or transport safety for the indicator describing this aspect of the sustainability of the city transport.
3. **Default value variable:** are present in the formulae to calculate the indicator value. It can be replaced with a city-specific value if cities have more appropriate values available.
4. **Conversion value variable:** fixed values based on scientific research or scientific relations between some of the other variables.
5. **Output variable:** the result of the formula calculation, indicating the parameter value for the sustainability indicator concerned.
6. **Calculated value:** intermediate calculation results, to be used in later in the indicator calculation process.
7. **Informative input variable:** not used in the parameter calculation, but can be used for local, city relevant calculations.

Some variables that were used for parameter calculation and their sources are:

- **Population data:** The number of population data is collected from Ethiopian central statistical agency and from UN, Department of Economic and Social Affairs Population Division www.worldometers.info (real time world statistics).
- **Number of vehicle data:** the number of cars (vehicles) in Addis Ababa is collected from Addis Ababa Transport office and from different websites
- **Traffic Accident rate in Addis Ababa:** from Addis Ababa Traffic Police Office, Addis Ababa Traffic Management Agency and from different web sites
- Data about the traffic condition in Addis Ababa, the trends of development, land use and transport policies, regulations, proclamation and directives were explored and collected from literatures and the AACAA and Federal Transport Authority documentation sections.

3.4. Methodology for Analysing the Data

Indicator Parameter Calculation: A description for each of selected indicators and a parameter to measure its sustainability score was established after an extensive literature study. These parameters are obtained by means of formula calculation, extraction from previous studies or other methods. A detailed clarification of what to do for each of the parameters can be found in chapter 4. A spreadsheet comprising list of indicator with their corresponding calculation technique was prepared and completely filled for data analysis.

Indicator Score Calculation: The score of the indicators are calculated based on the parameter value selected to describe the indicators. From the parameter value calculation, the indicator score is adjusted and decided from its position between the best and the worst parameter values as recommended from different literatures. This ranges from 5 to 1 where a score of 5 indicate a sustainable performance for the city in that aspect and 1 designating the worst condition.

Final Presentation: it is proposed to represent the scores of set of indicators on a spider chart at the end. By giving this disaggregated overview of the sustainable mobility performance, the city can identify its strength and weaknesses. Furthermore, the spider chart or radar enables the observation of how indicators are interconnected in the sense that it is possible to see how some solutions impact simultaneously on several indicators. A trend analysis is also performed for some indicator.

CHAPTER 4: RESULTS AND DISCUSSIONS

The main intention of a sustainability assessment is to include the most important local indicators in the assessment model. An assessment model with a comprehensive inclusion of key issues provides findings that will be very beneficial to an inclusive decision-making ground to support development of policies and effective measures for a more sustainability urban future. Sustainability model is characterized with three main aspects, i.e., environmental, economic and social. But it is not completely adequate just to gain the knowledge about the importance of indicators to achieve a sustainability transportation system. A structure is needed to determine if the transportation system is progressing towards sustainability.

This chapter gives a definition for each of the indicators and a parameter to measure its sustainability score. These parameters are obtained by means of formula and methods that are described below. A detailed clarification of what to do for each of the parameters can also be found. A spreadsheet comprising list of indicator with their corresponding calculation technique was prepared and completely filled for data analysis.

4.1. Indicator Analysis Explanation

A more detailed indicator analysis explanation can be found here, which deals with the methodology and scaling of each of the indicators separately. In the following pages the different types of input data sources are described further in general, specifying what type of data source is most appropriate for each of the indicators.

4.1.1. Social Indicators

1. Road Serviceability

Definition: is a ratio between total lengths of road with number of population in the city.

Parameter: Road network length per population (Road density per population)

Methodology: The unit of this index is km/people. This indicator shows the availability of roads for peoples in the city. The data needed to compute this indicator are total length of road constructed in the city and total number of population of the city.

To calculate the road density first determines the total length of road network constructed until 2010 E.C including asphalt, gravel and coble stone and the total population of Addis Ababa. Then calculate the Road network length per 1,000 inhabitants

Formula and calculation method: $RS = \frac{\text{Total road network length}}{\text{population}}$

Input Data Source: Using existing databases from AACRA and CSA

Scale: 1 referring to $RS < 2.5\text{km}/1000\text{inh}$ whereas 5 is for $RS > 5.5\text{km}/1000\text{inh}$

2. Inclusive Access/ Accessibility for all

Definition: The accessibility for mobility impaired groups to transport and transport services. Elements of convenient accessibility for deficiency groups are, for example, the availability of special provisions for disabled people or elderly in public transport, provisions for blind people on walkways and in railway stations, seats reserved for disabled people and the elderly in buses, reserved parking spaces for the disabled.

Parameter: Average reported convenience of city transport for target groups.

Methodology

- **Description:** Survey methodology will be employed and the target population is selected groups: people with (registered) visual disabilities or reduced mobility, pregnant women.
- **Source:** Wennberg, H., C. Hyden, A. Stahl (2010), Transport policy, vol. 17; 464-474.

Formula & Calculation method: take average value of all responses with a weighting form the most satisfied to least satisfied responses. Alternatively, one can calculate the variable of the average survey score using the following formula.

$$AccDGsc_{av} = \frac{\sum_i AccDGsc_i}{m}, \quad AccDGsc_i = \frac{\sum_j AccDGsc_{ij}}{n_i}$$

$AccDGsc_{av}$ = Averaged score of accessibility for deficiency groups of city transport. [%]

$AccDGsc_i$ = Averaged score of deficiency group i. [%]

$AccDGsc_{ij}$ = Averaged score of accessibility for deficiency group i by sub question j [%]

i = Deficiency group considered, n_i = Number of questions in survey related to deficiency group i [#] and m = Number of deficiency groups considered. [#]

Input Data : Necessary raw/unprocessed data from surveying were extracted for parameter calculation. Minimum size of the sample to represent the target population was checked. The sample unit includes blind, deaf and physically disabled individuals who are living in Addis Ababa city. The Participants were selected randomly using small population size sampling method. (Tilahun, 2017). Averaged score of deficiency group i by inquires j is presented in following table.

Table 4-1: Average score of deficiency group by selected inquiries

Deficiency group considered	Blind	Physically impaired	Deaf
Accessibility of the public transport stops	1.81	1.60	2.31
Access of the public transport vehicles at the stops or stations	2.08	1.89	3.00
Provision of specialized space on public transport	1.66	2.15	3.64
Quality of the sidewalks	1.71	2.55	3.28
Ease of crossing the roads	1.91	1.52	2.40
Quantity of disabled parking spaces	1.61	2.46	3.19
Location of disabled parking spaces	1.25	2.06	2.62
Guidance and warning systems for disabled people along sidewalks	1.22	2.49	3.04
Changing modes of transport	1.91	2.12	3.22
Narrow seating space	2.00	1.55	2.40
Getting information about accessible transport	1.79	2.66	2.64

Calculation:

Averaged score of deficiency group i $AccDGsc_i = \frac{\sum_j AccDGsc_{ij}}{n_i}$

n_i : Number of inquiries in survey related to deficiency group =11

$AccDGsc_{Blind} = 18.95/11 = 1.72$

$AccDGsc_{Physically\ impaired} = 23.05/11 = 2.09$

$AccDGsc_{Deaf} = 31.74/11 = 2.89$

Averaged score of accessibility for deficiency groups..... $AccDGsc_{av} = \frac{\sum_i AccDGsc_i}{m}$

m : Number of deficiency groups considered = 3

$AccDGsc_{av} = 6.704/3 = 2.23$

3. Access to mobility services

Definition: Share of population with appropriate access to mobility services.

Parameter: Percentage of population living within walking distance of public transport (stop or station) or shared mobility (car or bike) system in metropolitan area

Methodology

- **Description:** this parameter is the percentage of people living within a straight-line distance of 400 meters from a public transport stop or 800 meters from a rail transport stop. The percentage of people living within the service areas can be calculated by using spatial data – GIS using the Buffer Wizard (e.g. with software ArcGIS and ArcView). The Buffer Wizard allows rings to be drawn around features (points, lines or polygons) at a specified distance from that feature. The necessary data are two different shape files, one with public transport stops and one with the population.
- **Source:** Transport for London (2010), Measuring Public Transport Accessibility Levels and Center for Transportation Research – University of Texas (2005), Measuring Access to Public Transportation Services: Review of Customer Oriented Transit Performance Measures and Methods of Transit Submarket Identification

Formula & Calculation method:
$$AccI = \frac{\sum_i PR_i}{inh}$$

AccI = Appropriate access Index [% of population]

PR_i = Number of people living within acceptable radius of a station (or stop) of public or shared mode i [#]

inh = Capita or number of inhabitants in the city [#]

Input Data: subsequent table shows the necessary processed data extracted from spatial data analysis for parameter calculation. According to Aklilu & Necha (2018), estimated potential population accessible within 0–800-m walking distance can be found by multiplying population density with service area coverage for 400- and 800-m walking distances.

Table 4-2: Estimated potential population accessible within 0–800-m walking distance

ADDIS ABABA	Population	Area km ²	Population density(inh/km ²)	SA	PR
Akaki Kaliti-Sub City	227,182	123.4	1,841.0	62.2	114511.51
Nefas Silk-Lafto-Sub City	396,486	58.7	6,754.4	27.9	188111.33
Kolfe Keraniyo-Sub City	537,561	63.4	8,478.9	30.2	256062.18
Gulele-Sub City	335,434	31.1	10,785.7	14.1	151538.51
Lideta-Sub City	252,842	9.1	27,784.8	4.1	112528.58
Kirkos-Sub City	277,346	14.6	18,996.3	7.3	138673.00
Arada-Sub City	265,141	9.5	27,909.6	4.8	132570.50
Addis Ketema-Sub City	320,053	8.6	37,215.5	3.8	141418.77
Yeka-Sub City	434,599	82.1	5,293.5	39.6	209359.20
Bole-Sub City	387,355	118.5	3,268.8	57.3	187139.86
					1631913.45

Access Index [% of population]
$$AccI = \frac{\sum_i PR_i}{inh} = 47.62\%$$

Scale: 1 referring to AccI = 0 [% population] whereas 5 for AccI = 100 [% population]

4. Traffic Safety

Definition: Transport accidents in the city and damage caused in the city. OECD concluded that is not possible to identify reliable and comparable figures of injuries due to underreporting of transport injuries and too divergent local definitions. Global Status Report on Road Safety by WHO (2013) also put forward that non-fatal crash injuries are poorly documented. Different definitions of injury severity further complicate reporting of injuries. Therefore, the advice is to limit the indicator to fatalities.

Parameter: Number of deaths within 30 days after the traffic accident as a corollary of the event per annum caused by urban transport per 100,000 inhabitants

Methodology

- **Description:** Indicator is based on the existing databases, mainly Statistics of Road Traffic Accidents. Reported data should be in the form of annual transportation fatalities per 100,000 people. This adjustment is needed for the purpose of comparability of data along with target values as well as scoring purposes.

Formula & calculation method:
$$FR = \frac{\sum_i K_i * 100000}{inh}$$

FR = Fatality rate [# per 100.000 population per year]

K_i = Number of fatalities in transport mode i [# per year]

inh = Number of inhabitants (capita) in the city [#]

i = Transport mode (passenger car, bus, motorcycle, etc.) [Type]

Input Data: The following data taken from Addis Ababa Traffic Police Office and Addis Ababa Traffic Management agency was used for parameter calculation.

Table 4-3: Traffic accidents by vehicle classification

Severity Type	Vehicle type																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	Bicycle	Motor Bicycle	Automobile	Station wagon	Pick up (<10 Quintals)	Dry Cargo(11-40 Quintals)	Dry Cargo(41-100 Quintals)	Trailer	Liquid Cargo	Taxi	Bus (up to 12 Seats)	Bus (13-45 Seats)	Bus (>46 Seats)	Leyu Gotach	Cart	Other	Unclassified	Total
Fatal	-	2	136	-	41	66	61	12	-	45	31	19	-	-	-	-	50	463
Sever Injury	5	55	267	146	357	78	65	7	1	389	356	126	14	1	3	0	126	1996
Slight Injury	3	83	148	51	151	74	40	4	2	161	185	21	5	1	5	3	36	973
Property Damage	31	206	4158	1749	3443	1810	1177	303	40	5257	2998	1242	512	20	17	354	193	23510
Total	39	346	4709	1946	3992	2028	1343	326	43	5852	3570	1408	531	22	25	357	405	26942

Table 4-4: Fatality rate (# per 100,000 population per year)

Severity Type	2010	2011	2012	2013	2014	2015	2016	2017
Fatal	318	332	369	367	391	416	439	463
Sever Injury	626	904	1,190	1,336	1,484	1,669	1,924	1,996
Slight Injury	650	831	820	1,263	1,127	1,098	1,165	973
Property Damage	4,689	7,058	9,150	12,849	14,902	17,249	19,411	23,510
Total	6,283	9,125	11,529	15,815	17,904	20,432	22,939	26,942

Analysis

Fatality rate=	fatalities/population							
FR	9.35	9.76	10.85	10.79	11.50	12.24	12.91	13.62

Scale: 1 referring to FR >35 fatalities/100,000 inh whereas 5 is for 0 fatalities/100,000 inh

5. Availability of Public Transport

Definition: Availableness of public transport for the population

Parameter: Average number of inhabitants per PT vehicle

Methodology Description: PT size in relation to population could indicate the availableness of public transport for the inhabitants. The ratio of number of inhabitants in the city to total number of public transport vehicles gives the adequacy of PT size in that region. The unit of this index is inh/vehicle.

Formula and calculation method:
$$PT_{size} = \frac{Population}{PT\ vehicles}$$

Input Data: The following data were taken from Addis Ababa Road and Transport Bureau for calculation purpose.

Table 4-5: Public transport modes and number of passenger per vehicle

Vehicle Type(PT mode)	No. of vehicle	Capacity of vehicle (passenger/vehicle)
Anbessa City Bus	458	90
Alliance Bus	125	70
Sheger Bus	330	70
Higer Bus	418	37
Midi-Bus	376	37
Minibus (code 1)	5561	12
Minibus (code 3)	11688	12
Train	41	300
Public Bus	410	70
Lada-Taxi	7557	4
Meter Taxi	1163	4
Airport Taxi	451	4
Total	28,578	710

Numbers of Operating PT vehicles in Addis Ababa according to AARTB, Public and Freight transport Authority are as shown above. The Bureau states vehicles with capacity of ≥ 70 passengers as mass transport and those of with lesser passengers are public transport. To meet the objective of this study lower capacity vehicle were not considered and only sustainable modes are added for calculation.

$$PT_{size} = \frac{Population}{PT\ vehicles} = 3.4 * 10^6 / 2158 = 1,576 \text{ inh/vehicle}$$

Scale: 1 referring to PTsize > 1450 inh/vehicle whereas 5 is for PTsize < 400 inh/vehicle

6. Opportunity for active mobility

Definition: Options and infrastructure for active mobility, which refers to the use of the soft modes, namely walking and cycling.

Parameter: The length of roads and streets with sidewalks and bike lanes related to total length of city road network (excluding motorways).

Methodology

- **Description:** The indicator measures the spaces where active mobility is possible; therefore, this indicator is calculated as the percentage of the length of roads and streets with sidewalks and biking lanes related to total length of city road network. This ratio is preferably obtained using spatial data and GIS. An alternative is using existing data of road length.

Formula and calculation method:
$$R_{am} = \frac{L_{sw} + L_{bl}}{L_{rn}} * 100$$

Ram = Share of road length adapted for active mobility [%]

Lsw = Length of road network with sidewalks [km]

Lbl = Length of road network with bike lanes [km]

Lrn = Total length of city road network [km]

Input Data: AACRA's spatial data and the corresponding excel on Road inventory 2010 E.C was used for parameter calculation. Since there is no road network with bike lanes, only length of road network with sidewalks is considered with respect to total length to calculate share of road for active mobility.

Scale: 1 referring to Ram = 0 [% road length] whereas 5 for Ram ≥ 200 [%]

4.1.2. Environmental indicators

1. Road Availability/Density

Definition: a ratio between total lengths of road per surface area of the city

Parameter: Road network length per land take/surface

Methodology

- **Description:** a ratio between total road lengths with area width. Road availability has a unit km/km². The road density explains how dense the road network is in the study area and we have to compare the result with some standards. If the value of road density shows increasing through years which means construction of new roads in the city giving more access to the peoples.

Formula and calculation method: $RD = \frac{\text{Total road network length}}{\text{Area}}$

Input Data Source: The data needed to compute road density are the trend of total road length constructed which is collected from AACRA and total area of the city collected from the sub-cities and when we divide the two numbers we will get the road density of the city.

Scale: 1 referring to RD >13 km/km² whereas 5 is for RD < 4 km/km²

2. Ease of use of affordable transport modes like walking and cycling

Definition: the availableness of affordable and alternative transport modes like waking and cycling Road in the city

Parameter: Pedestrian infrastructure density and cycling infrastructure density

Methodology

- **Description:** Affordable and alternative transport modes route network as a proportion of total road network. Availability of these alternative modes has a unit km/km² or percentages. Pedestrian infrastructure density can be calculated as a ratio of sidewalk length per km² of surface area and cycling infrastructure density as cycle route network as a proportion of total road network

Formula and calculation method: $P_{inf.density} = \frac{Total\ sidewalk\ length}{Area}$

$$C_{inf.density} = \frac{Cycle\ Route\ Network}{Total\ Road\ Network}$$

Input Data Source: Spatial data Analysis (using GIS), Extraction of necessary processed data from AACRA's spatial data analysis for parameter calculation

Scale: 1 referring to $P < 0.2$ km/km² whereas 5 is for $P > 0.5$ km/km²
1 referring to $C < 9\%$ whereas 5 is for $C > 36\%$

3. Public Transport infrastructure Density

Definition: Public transport network length per surface area

Parameter: PT infrastructure density

Methodology: Public transport infrastructure density can be calculated as a ratio of public transport network length per km² of surface area. The index unit is km/km²

Formula and calculation method: $PT_{inf.density} = \frac{Total\ PT\ inf\ rastructure\ length}{Area}$

Data Source: Extraction of required processed data from AACRA's spatial data analysis

Scale: 1 referring to $P = 0.2$ km/km² whereas 5 is for $P > 4$ km/km²

4. Emission from Greenhouse Gases (GHG)

Definition: total emissions of GHG emitted by all city transport modes

Parameter: Ton CO₂ equivalent emissions by urban transport per year per capita

Methodology

- **Description:** This indicator measures the total emission of GHG per capita emitted by all city transport modes (freight and passenger, public and private). Road transport is an important source of greenhouse gas emissions (United Nations, 2004). Emissions from

fossil fuels can be from gasoline fuels or diesel fuels. A vehicle is moved by burning fuel in an engine and its by-products are released in the combustion process into the surrounding environment and the majority of motor vehicles worldwide are powered by gasoline or diesel fuels.

Formula and calculation method:
$$GHG = \frac{CO_2 \text{ ton} * P_{tran}}{inh}$$

GHG = Greenhouse gas emission [tons CO₂(eq) /cap. per year]

CO₂ton = million tons of carbon dioxide gas (CO₂) the city emits

P_{tran} = percentage of transport vehicles that account form the total emission

Inh = Capita or number of inhabitants in the city [#]

Input Data: For purpose of this study, data from Addis Ababa Greenhouse Gas Emission Inventory was used. Among the 4.8 million tons of carbon dioxide gas (CO₂) the city emits, transport vehicles account for 47 percent of the total emission. This was also confirmed by Molalign Wolde (2016) and Teshome Worku. They also mentioned the total passenger transport in passenger-km in Ethiopia is expected to increase from 40 billion in 2010 to 220 billion in 2030 driven by a strong urbanization. If business goes as usual, emissions from the motor vehicles will increase from 5 million ton CO₂ in 2010 to 41 million-ton CO₂ in 2030.

GHG EMISSION.....
$$GHG = \frac{CO_2 \text{ ton} * P_{tran}}{inh} = \frac{4.8 * 0.47}{3.4} = \frac{2.256}{3.4} = 0.66$$

Scale: 1 for GHG ≥2,75 tons CO₂(eq)/cap and 5 is for 0 tons CO₂(eq)/cap.

4.1.3. Economic indicators

1. Affordability of public transport for the poorest group

Definition: Share of the public transport cost for fulfilling basic activities of the household budget for the poorest quartile of the population.

Parameter: Affordability index of public transport for the poorest population quartile based on the relation between the cost for 60 relevant public transport trips and the average monthly household income

Methodology

According to Carruthers, Dick, & Saurkar (2005) and WBCSD (2016), it evaluates the ability to make necessary journeys to work or school, for health and other social services, and to make visits to other family members and friends or other urgent journeys, especially within the city, without having to curtail other essential activities. The definition suggests that the cost of transport has to be seen in relation to the household budget and a fixed number of 60 necessary trips of 10km per month are assumed. A more affordable system is one that consumes a smaller share of users' incomes.

Source: taken from the methodology used by the World Bank in Latin American cities Carruthers, R., M. Dick and A. Saurkar (2005), "Affordability of Public Transport in Developing Countries", Transport Papers, The World Bank Group: Washington

Formula & Calculation method:
$$AI = \frac{\sum_i TPT_i * F10km_i * 60}{Minc_{25\%}}$$

AI = Affordability Index of public transport for poorest population [% of HH income]

MPT_i= Monthly percentage of PT trips with PT mode i [%]

F10km_i = Fare 10km PT trip with PT mode i [monetary unit]

Minc_{25%} = Average monthly income of poorest population quartile [monetary unit]

i = Available public transport mode [type] & 60 = sixty trips per month

Input Data: The desired data for parameter calculation were taken from AARTB, Public and Freight transport Authority and AACA and are presented as follows

Table 4-6: PT vehicles Fare structure

a) Anbessa Bus

	Distance (in km)	Tariff (in ETB)
1	Upto 5	1.50
2	9 - 12	2.00
3	12 - 15	2.70
4	15 - 18	2.80
5	18 - 21	3.50
6	21 - 24	4.25
7	24 - 30	5.00
8	30 - 47	9.00

b) Alliance and Sheger Bus

	Distance (in km)	Tariff (in ETB)
1	Upto 4	1.50
2	4.1 - 6	2.00
3	6.1- 8	2.55
4	8.1- 9	3.05
5	9.1- 10	3.55
6	10.1- 12	4.05
7	12.1- 13	4.55
8	13.1- 15	5.05

c) Minibus

	Distance (in km)	Tariff (in ETB)
1	Less than 2.5	1.50
2	2.6 - 5.0	3.00
3	5.1 - 7.5	4.50
4	7.6 - 10.0	6.00
5	10.1 – 12.5	7.50
6	10.1 – 12.5	9.00
7	15.1 – 17.5	10.50
8	17.6 – 20.0	12.00
9	20.1 – 22.5	13.50
10	22.6 – 25.0	15.00
11	25.1 – 27.5	16.50
12	27.6 – 30	18.00

d) Higer Midi-bus

	Distance (in km)	Tariff (in ETB)
1	Less than 8	2.50
2	8.1 – 12.0	3.50
3	12.1 – 16.0	4.75
4	16.1 – 20.0	6.00
5	20.1 – 24.0	7.00
6	24.1 – 28.0	8.25

Table 4-7: Affordability Index of public transport

Mode _i	No of trips daily	No of trips monthly	MPT _i	F10km _i	
Anbessa City Bus	3,664	109,920	1.40%	2.00	0.028
Alliance Bus	1,250	37,500	0.48%	3.55	0.017
Sheger Bus	3,300	99,000	1.26%	3.55	0.045
Higer Bus	5,016	150,480	1.92%	3.50	0.067
Midi-Bus	4,512	135,360	1.73%	3.50	0.061
Minibus(code 1)	77,854	2,335,620	29.84%	6.00	1.790
Minibus(code 3)	163,632	4,908,960	62.71%	6.00	3.763
Train	492	14,760	0.19%	4.00	0.008
Public Bus	1,064	23,408	0.30%	0.00	0.000
Public for external use	576	12,672	0.16%	2.00	0.003
			$\sum MPT_i * F10km_i =$		5.782
AFFORDABILITY INDEX	$AI = \frac{\sum_i TPT_i * F10km_i}{Minc_{25\%}} * 60$		= 22.49%		

Scale: 1 referring to A.I. >35%, whereas 5 is for A.I. < 3.5%

2. Mobility space usage

Definition: The Proportion or efficiency of land use taken by all city transport modes including direct and indirect uses. Efficiency refers indirectly to mobility output by referencing total population.

Direct land use by city transport refers to the area covered by transport infrastructure such as roads and streets and squares used to move people and for vehicles. Indirect land use by city transport refers to indirect uses such as off-street parking areas, security areas, service areas, stations, inland port hubs, storage areas and distributions centers for city freight transport.

Parameter: Square meter of direct and indirect mobility space usage per capita

Methodology

- **Description:** The efficiency of mobility space usage is calculated by the ratio of the area covered by all city transport modes, including direct and indirect uses, to the total population of the city.
- **Source:** The described methodology is based on information from the Victoria Transport Policy Institute (VPTI, “Evaluating Transportation Land Use Impacts”, (2012), p. 11-16)

Formula & Calculation method:
$$LUM = \frac{\sum_i (LD_i + LI_i)}{inh}$$

LUM = Land use for mobility applications [m²]

LD_i = Direct Land use for mobility mode i [m²]

LI_i = Indirect Land use for mobility mode i [m²]

i = Mobility mode[#]

inh = Capita or number of inhabitants in the city [#]

Scale: 1 referring to $LUM \geq 125$ (m²/inh) whereas 5 is for $LUM \leq 25$ (m²/inh). Land use for car traffic is almost the same amount as for housing (Litman T.,2012). A minimum score of 125 m² is chosen.

4.2. Valuation and Normalization of Indicators

It is worth mentioning that many local authorities of Addis Ababa were able to provide only few structured and organized data concerning the monitoring of the city's transport system. In order to cope with this deficiency, specific assumptions, such as homogenous yearly growth factors, were applied in order to bring the available primary data to the same base year and calculate the corresponding indicators as well as for trend analysis. The results from the assessment of the indicators are presented in Table 4-1.

The assessment of a combined expression of the sustainable mobility conditions requires the composition of the indicators that describe environmental, social and economic sustainability. With the intention of composing these indices using a common measuring system, the results of the indicators were ranked in a scale from 1 to 5 as described in the methodology section. The range of values per score for each indicator is based on calculation made from min and max scales that were derived from different researches. Each of these sources can be found in the corresponding indicator analysis explanation. The normalization of indicators was done accordingly and indicator ranking system as well as the respective score is shown in Table 4-2.

Table 4-8: Results from assessment of indicators

Indicator	Description	Parameter	Unit	Value	Min Scale	Max Scale
1	Road Serviceability	Road network length per population	RS	km/1000inh	1.84	2.5 5.5
2	Accessibility for all/Equity	Accessibility of mobility-impaired groups	AccDG	%	15.29	30 90
3	Access/PT Network coverage	Share of population with appropriate access to mobility services	AccI	%	47.62	0 100
4	Traffic safety	Traffic related fatalities caused by urban transport per population	FR	fatalities/100000 inh	13.62	35 0
5	Availability of Public Transport	PT size per population	Ptsize	inh/vehicle	1,576	1450 400
6	Opportunity for active mobility	Length of cycling and walking paths to total length of road network	Ram	%	95.48	0 200
7	PT density per population	PT network length per population	Ptdensity	km/1000inh	0.80	0.1 1.7
8	Road Availability (Road Network Density)	Road network length per land take/surface	RD	km/km ²	11.59	13 4
9	Pedestrian infrastructure density	Availability of affordable transport modes (walking)	Pinf density	km/km ²	0.27	0.2 0.5
10	Cycling infrastructure density	Availability of affordable transport modes (cycling)	Cinf density	%	0.00	9 36
11	PT infrastructure density	Public transport network length per surface area	PTinf density	km/km ²	2.72	0.2 4
12	GHG	Emissions of greenhouse gases	GHG	tons CO ₂ (eq)/cap	0.66	2.75 0
13	Age of vehicle fleet	Average age of PT vehicles	Avg age	Years	23.00	19 4
14	Engine technology of PT fleet	Proportion of PT vehicle fleet meeting certain air emission standards	PT aes	%	41.98	0 60
15	Share of PT in modal split	PT as an average share of modal distribution of traffic	share PT	%	36.11	0 40
16	Vehicle Ownership	Number total vehicles per population	no of veh	veh/1000inh	140.9	600 300
17	Public Finance	Net public finance	PF	%	-2.40	-2.5 0
18	Affordability of public transport for the poorest group	Share of the public transport cost for fulfilling basic activities	AI	%	22.49	35 3.5
19	Mobility space usage	Area of direct and indirect mobility space usage per capita	LUM	m ² /capital	37.55	125 25

Table 4-9: Indicator Ranking system and their score

Indicator	Value	Signing of indicator value with reference to positive or negative impact along with their respective scales						Score	
		Sign	1	2	3	4	5		
1	Road Serviceability	1.84 km/1000inh	+	<2.5	2.5-3.5	3.5-4.5	4.5-5.5	>5.5	1
2	Accessibility for all/Equity	15.29 %	+	<30	30-50	50-70	70-90	>90	1
3	Access/PT Network coverage	47.62 %	+	0-20	20-40	40-60	60-80	80-100	3
4	Traffic safety	13.62 fatalities/100000 inh	-	>35	35-23.33	23.33-11.67	11.67-0	0.00	3
5	Availability of Public Transport	1,576 inh/vehicle	-	>1450	1450-1100	1100-750	750-400	<400	1
6	Opportunity for active mobility	95.48 %	+	0-40	40-80	80-120	120-160	160-200	3
7	PT density per population	0.80 km/1000inh	+	<0.10	0.10-0.63	0.63-1.17	1.17-1.7	>1.70	3
8	Road Availability/Network Density	11.59 km/km2	-	>13.00	13-10	10-7	7-4	<4.00	2
9	Pedestrian infrastructure density	0.27 km/km2	+	<0.2	0.2-0.3	0.3-0.4	0.4-0.5	>0.50	2
10	Cycling infrastructure density	0.00 %	+	<9	9-18	18-27	27-36	>36	1
11	PT infrastructure density	2.72 km/km2	+	<0.20	0.2-1.46	1.47-2.73	2.73-4	>4.00	3
12	GHG	0.66 tons CO2(eq)/cap	-	>2.75	2.75-1.83	1.83-0.92	0.92-0	0.00	4
13	Age of vehicle fleet	23 Years	-	>19	19-14	14-9	9-4	<4	1
14	Engine technology of PT fleet	41.98 %	+	0-15	15-30	30-45	45-60	>60	3
15	Share of PT in modal split	36.11 %	+	0-10	10-20	20-30	30-40	>40	4
16	Vehicle Ownership	140.9 veh/1000inh	-	>600	600-500	500-400	400-300	<300	5
17	Public Finance	-2.40 %	+	<-2.5	-2.5_-1.67	-1.67_-0.83	-0.83_0	0.00	2
18	Affordability of PT	22.49 %	-	>35	35-24.5	24.5-14	14-3.5	<3.5	3
19	Mobility space usage	37.55 m2/capital	-	>125	125-91.67	91.67-58.33	58.33-25	25.00	4

4.3. Sustainability Assessment

The score (1 to 5) of the indicators are calculated based on the parameter value selected to describe the indicators. The results of these representative 19 indicators are presented graphically as below. The sustainability analysis is presented using a spider chart. By giving this disaggregated overview of the sustainable mobility performance, one can identify the strength and weaknesses. Regarding the diagrams presented, it can be seen that five indicators out of nineteen get the lowest score (i.e. one) while only one indicator is ranked to the highest level. Seven indicators got a moderate result with score of 3. The average score of the environmental category is 2.33 while the scores of the social and economic categories are 2.13 and 3.6 respectively.

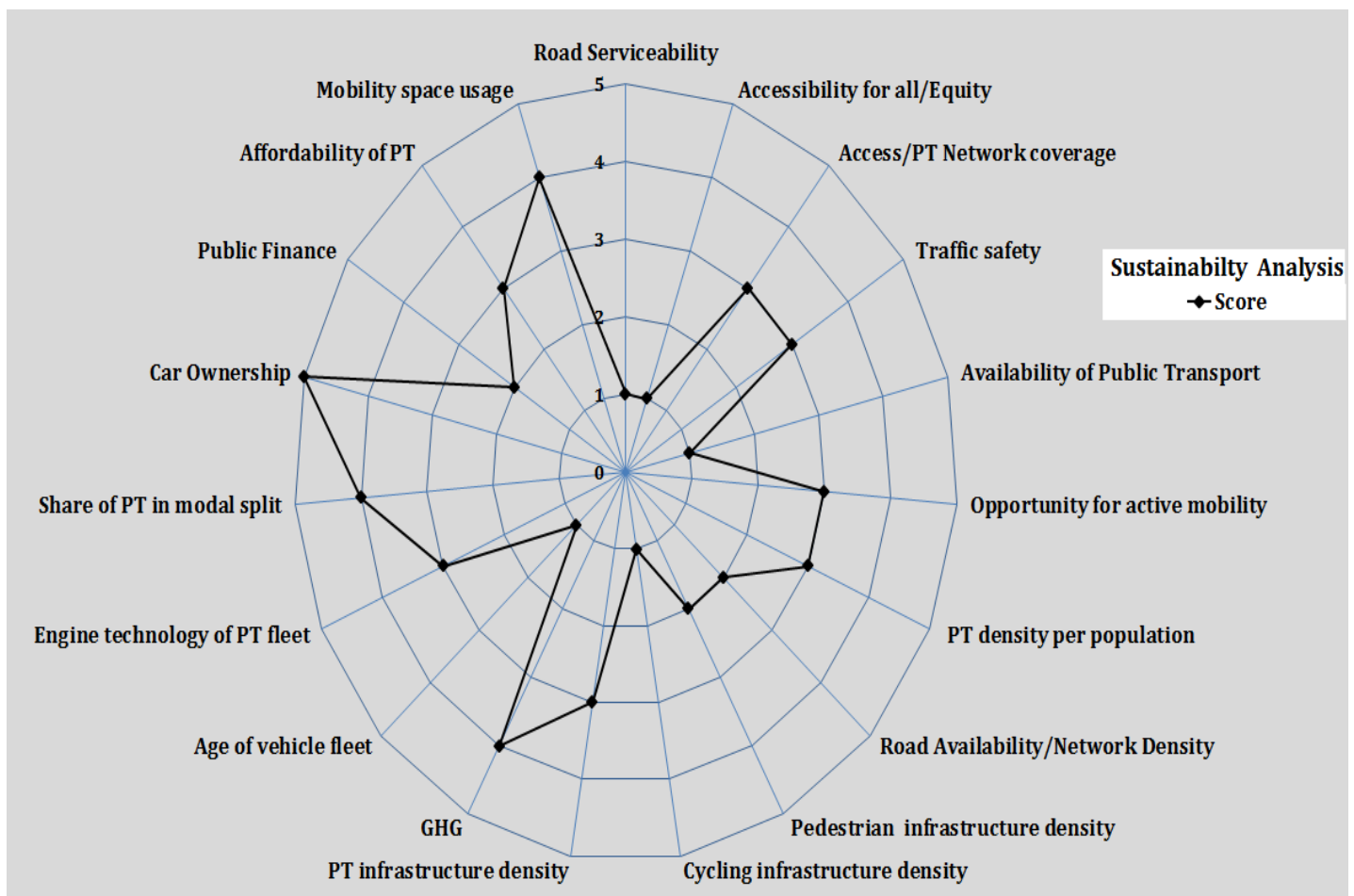


Figure 4-1: Ranking Scores of indicators

Sustainable City Transport Composite value: The normalization of the indicators enables the assessment of the sustainability of city transport system. The initial step towards this purpose is the definition of weights that are attributed to each indicator category to express the gravity that environmental, social and economic sustainability holds in relation to the overall goal of sustainable urban mobility. In the international literature, various methods are applied for defining these weights that can be divided into two main approaches, i.e. the use of equal weights and the use of an evaluation method, such as multi-criteria analysis, in order to obtain weights (Singh et al. 2009; Castillo and Pitfield 2010). As Tanguay et al., 2010 described the main disadvantage of the first approach refers to its simplicity while the main disadvantage of the second approach refers to its subjectivity.

In this specific research, the method of equal weighting is chosen in order to avoid subjectivity

and calculation was made by the following equation:

$$\frac{\sum i_{so}}{n_{so}} + \frac{\sum i_{en}}{n_{en}} + \frac{\sum i_{ec}}{n_{ec}}$$

$$\frac{\quad\quad\quad}{n_{tot}}$$

Where *i* is score of each indicator and corresponding subscripts *so*, *en* and *ec* indicate the social, environmental and economic dimension category respectively. *n* stands for total number of indicator in the category.

According to the value of this composite sustainable calculation, four different levels of sustainable mobility conditions could be identified (Van Dijk and Mingshun 2005):

- a) Sustainable ≥ 4 ,
- b) $4 > \text{Moderate} > 3$,
- c) $3 \geq \text{Weak} > 2$ and
- d) $2 \geq \text{Unsustainable}$.

The sustainability for Addis Ababa city transport system is 2.69/5, suggesting weak sustainable mobility conditions for the city’s transport system (Figure below).

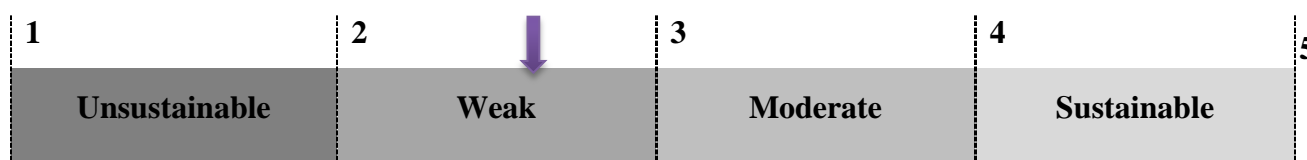


Figure 4-2: Sustainability condition of Addis Ababa City’s transport system

4.4. Discussion on Individual Indicator Score Results

Although the indicators' score tells the state of an overlapping objective and goals, the following general discussion was made on individual parameters classified under the three themes.

4.4.1. Indicators Related To Land Use, Transport Planning and Management

Due to the strong link between land use and transport, integrating planning is essential for sustainable development. The urban structure of a city determines the chances for sustainable urban transport. The choice for the most sustainable urban structure depends on many factors but in all cases adequate planning should be in place. Integrated planning is economically beneficial as it allows governments to save money on urban development and people to spend less time and money on transport. In addition, the reduction in travel distances and improved chances for more sustainable modes are clear environmental benefits of integrated planning.

Most of the indicators related to land use and traffic management score below half except mobility space usage with score of 4. The reason behind might be the proportion or efficiency of land use, taken by all city transport modes and transport infrastructure, are not as high as other sectors like building and constructions. Although the calculation of **mobility space usage** per capital shows good score, Addis would benefit from more balanced planning on efficient land use. Places assigned very few parking with respect to city area. There is no separate facility for cycle and other vehicles.

Road serviceability is among with minimum score that tells as a priority of improvement in realizing sustainability goals. The road network length per population should increase for efficient traffic management. Then again, **Road density**, the road network per land take is high getting a score of 2. This shows construction of auto oriented road infrastructures. As road availability/density explains how dense the road network is in the study area, if the value shows increasing through years it means construction of new roads in the city giving more access to the peoples. Nevertheless, construction of auto oriented road infrastructures encourages car use and ownership, which in turn results in congestion of the new highways or roads in a matter of time. Therefore the conventional way of planning and designing urban transport infrastructure, as opposed to sustainable planning, will result in the vicious circle of congestion as this practice will be accompanied by increase in the use of car and need of more roads.

Dirk Hebel (2009) highlights that Addis Ababa is implementing highway projects in a similar fashion as that of the 1950s US and is following the footsteps of an individualized transports system and beliefs of a motorized society. The road planning and design practice has to shift from the conventional way of planning of roads and highways for cars to multimodal and PT oriented planning in order to overcome the viscous circle of congestion.

4.4.2. Indicators related to Transport System Efficiency

Motorized transport, with its corresponding negative impacts, contributes for a large part in creating an unbalance between the three aspects of sustainable development: economic growth, social progress and environmental protection. A shift towards sustainable modes of transport (e.g. public and non-motorized transport) will therefore be helpful in the process of redressing the balance. Through an efficient, safe and affordable transport system, which provides choice in different modes of transport, accessibility of basic needs can be improved, many costs can be saved, productivity can be increased and thus both human and economic development can be improved. In addition, reduced pollution, less required space for transport and improved road safety will lead to improvement of the quality of life. Consequently, sustainable urban transport can positively influence the conditions within all three aspects of sustainable development.

In this aspect, to make the transport systems more efficient, cities should be walkable and an integrated multimodal urban transport system is needed. Some of the indicators that were used to quantify this include opportunity for active mobility, pedestrian and cycling infrastructure density, and accessibility to mobility service. These parameters also get lower scores indicating NMT receives very little attention despite the fact that it is dominate mode of transport, particularly walking. Addis Ababa lack adequate sidewalks and accessibility to public transport stations. Road intersections and pedestrian pathways (where they exist) are often taken by drivers using the space as parking, or by street sellers using the space for trading. In addition, it is often reported that cycling is regarded unacceptable due to the hilly topographic nature of the city. Worldwide, the development of safe pedestrian areas is seen as an essential step towards the development of livable streets and neighborhoods.

4.4.3. Indicators related to Public Transportation

Public transport has an important role in creating inclusive society as well as in promoting sustainable mobility and development. Even though Addis Ababa is one of the fastest growing cities in the world, yet is constrained by poor accessibility of city bus services. Kenea, Kinnear, & Akbar (2017) conducted an exploratory research and found that inadequate infrastructure, poor transport operation and ineffective performance of stakeholders have resulted in inaccessible service to the users. Aklilu & Necha (2018) also uses integrated spatial and statistical analysis to investigate the **spatial accessibility, user population and coverage**. The study explicitly showed potential users and daily average users are unbalanced. This study also reveals that share of population with appropriate access to mobility services is 47.6 % with moderate score of three but PT size per population is 1,576 inhabitant /vehicle with poor score of one. Generally, an increase in the accessible population is associated with an increase in the service area coverage. However, the population accessibility and service area coverage do not directly imply more number of actual users.

On the other hand, share of PT in modal distribution of traffic score good results as it is Addis's second major modal share next to walking. Nonetheless lower capacity vehicles (minibuses) account for about 70% of PT modal share with negative indication for sustainable mobility. Minibuses have proliferated by filling a void left by large-bus services. But they present clear disadvantages from the perspective of the public interest. Minibuses now account for almost 60 percent of all motorized traffic on some corridors. Their growth has produced severe congestion, particularly during peak periods. Most minibuses are old, inadequately maintained, and operated for long hours at low speed causing a drawback on safety and emissions.

Studies indicate that 20 per cent of the population of Addis Ababa is still too poor to afford the standard bus fare (Dagnachew, 2007). In contrast, the stakeholders believe that the fare of Anbessa city bus is affordable to the lower and middle-income group of the users that allows them to transit long distances between two corners of the city and neighboring towns. The share of the public transport cost for fulfilling basic activities of the household budget is about 22.49%. Even though public transportation is fully occupied even at current pricing, per indicator calculating criteria, Birr of 10 per commute is unaffordable for 60 trips per month for the poorest quartile and public transport is still expensive.

4.5. Trend Analysis

Sustainable cities cannot exist without sustainable mobility. In line with the results from the analysis, the sustainability for Addis Ababa city transport system scores 2.69 suggesting weak sustainable mobility conditions for the city's transport system. The sustainability analysis presented using a spider chart gives the disaggregated overview of the sustainable mobility performance that one can identify the strength and weaknesses. Indicators related to the accessibility and availability of PT and NMT (cycling and walking) score lower. The ages of vehicle fleet is also among the major concerns that should be well thought. While the number of total vehicles per population as well as emissions of greenhouse gases and mobility space usage score good results.

Thus, a shift towards more sustainable modes of transport like public and non-motorized transport is needed as it plays an indispensable role to make the cities livable and less polluted. In addition to the sustainability analysis, a trend analysis on vehicle growth was further studied to address it and see the change over time. For this growth to be sustainable, it has to show a higher rate of growth for public transportation modes when compared to private transportation modes (mainly passenger cars and minibuses). As discussed, since smaller buses are causing big problems their growth should be checked and examined in relation to mass transit.

Trend analysis helps to evaluate the sustainability of traffic growth in Addis Ababa. The number of registered vehicles was used as an indication of traffic growth. In addition, the number of registered buses is considered as an indication of PT usage. The trends for the rate of vehicles per capita and unit length of the road network will be discussed. Some of the data collected for parameter calculation for this analysis includes population data, GDP per capita, total number of registered vehicles along with their classification and total length of road network.

The analysis considers mainly two types of transportation modes for evaluation, public and private. The private transportation is represented by the number of private cars including taxis and low volume vehicles. Since the available data on vehicle registration does not differentiate the public buses from the other buses (such as, company, school and other buses), the total number of registered buses is considered as an indication of the trend of increase in public transportation.

Examining trend of growth in number of vehicle over time

The number of registered private passenger cars (PC) and buses from 2007/8 to 2016/17 can be summarized as shown underneath. It is clear that the vehicles have an increasing trend over the study period. In addition, the passenger cars show a rate of increase that is higher than that of the buses. Based on the regression analyses equations, the rate of increase of PC is 15.7 thousands per year but on the other hand, the rate of increase for buses is only about 1.3 thousand buses per year. Keeping in mind that there is no increase in railway track length and usage and the mentioned increase is the total increase in number of buses, not only for public buses, then the rate of increase in public transportation is much less than the increase in private transportation.

Table 4-10: Total number of registered vehicles

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PC	128,140	137,371	149,909	161,636	176,296	191,718	207,468	224,997	246,460	272,720
BUS	15,788	16,903	18,416	19,892	20,806	21,917	23,335	24,549	26,095	28,901
OTHER	65,430	76,659	85,864	95,383	104,765	118,700	131,869	144,357	159,744	176,973
Total vehicles registered	209,358	230,933	254,189	276,911	301,867	332,335	362,672	393,903	432,299	478,594

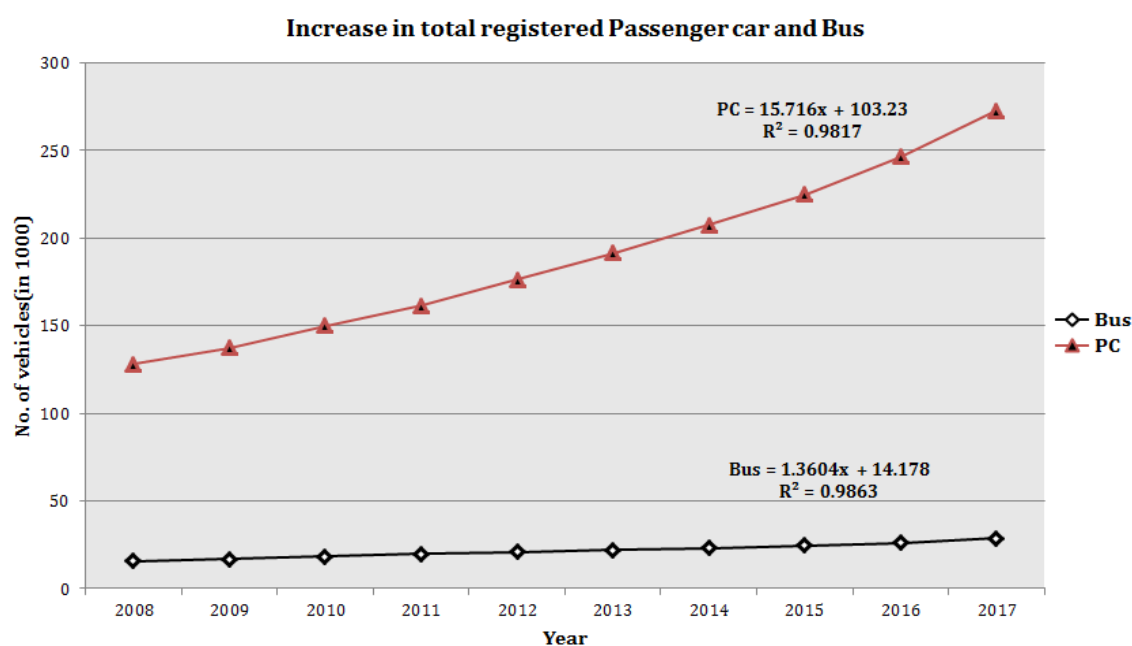


Figure 4-3: Trend of growth in number of each type of vehicle over time

Examining trends of change in traffic composition

Another way of considering the traffic composition is to consider the percentage of each mode out of the total number of registered vehicles. These percentages are illustrated in figures below, which shows that the percentage of buses out of the total registered vehicles is generally on average around 7%, while PC represents about 58% of the total vehicles registered in Addis Ababa city. In addition, the trends shown indicate that both the percentage of PC and buses is decreasing over the study period, because the percentage of other vehicles is rising. The growth in percentage of these other type of vehicles (like freight and machinery vehicles) is not a good indication, as it have been considered the major contributor to environmental pollution in the transport sector. Also, the reduction in the percentage of buses is a negative indication of unsustainable growth.

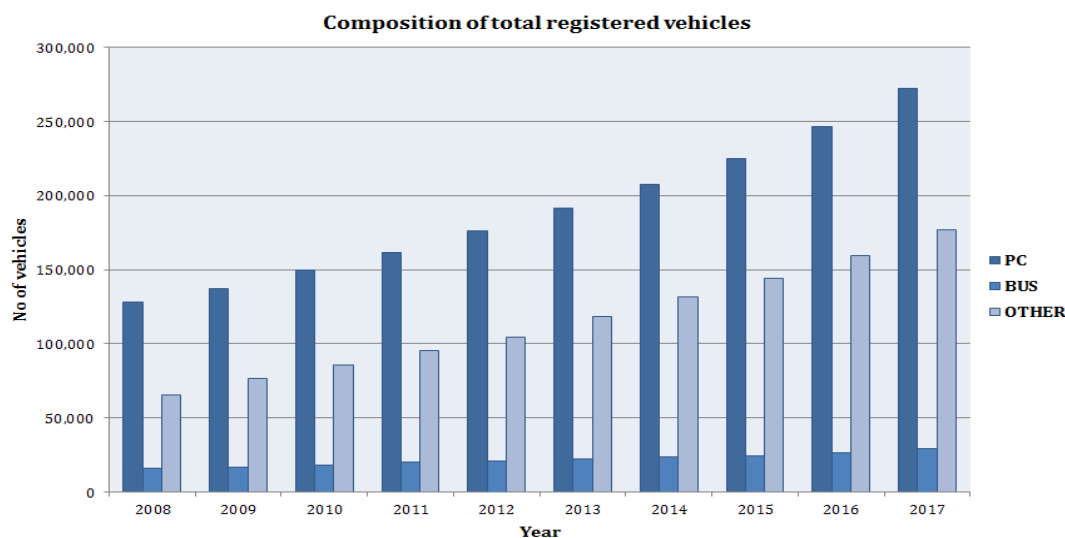


Figure 4-4: Change in traffic composition over time

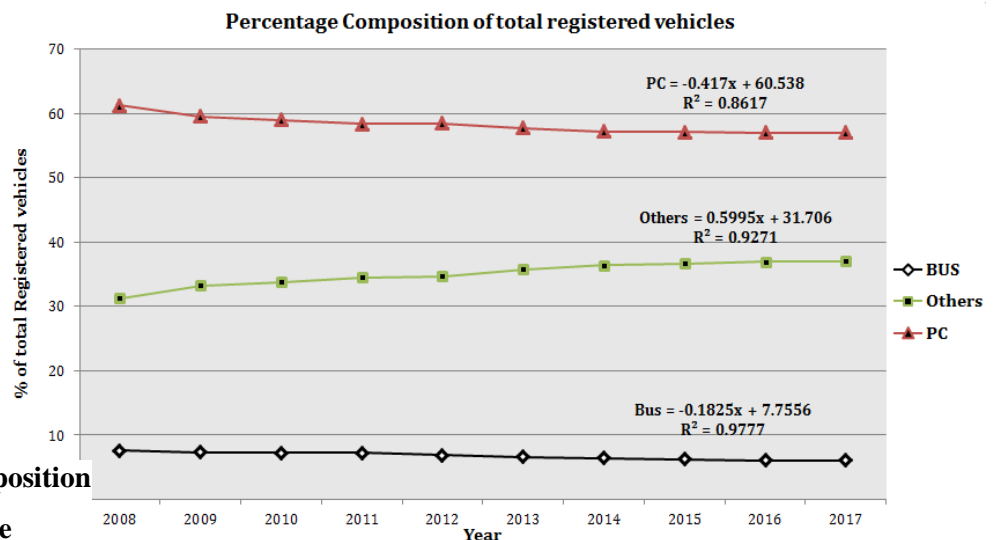


Figure 4-5: Trend of percentage composition of each type of vehicle over time

Examining the trend of change in number of vehicles per capita

The available population data reported by CSA was used in order to consider the population growth and the traffic growth combined. The number of vehicles per 1,000 capita is calculated and presented. It should be noted that the population for the study period years has been estimated based on the regression line equation. The data illustrates an increasing trend for types of vehicles considered per population.

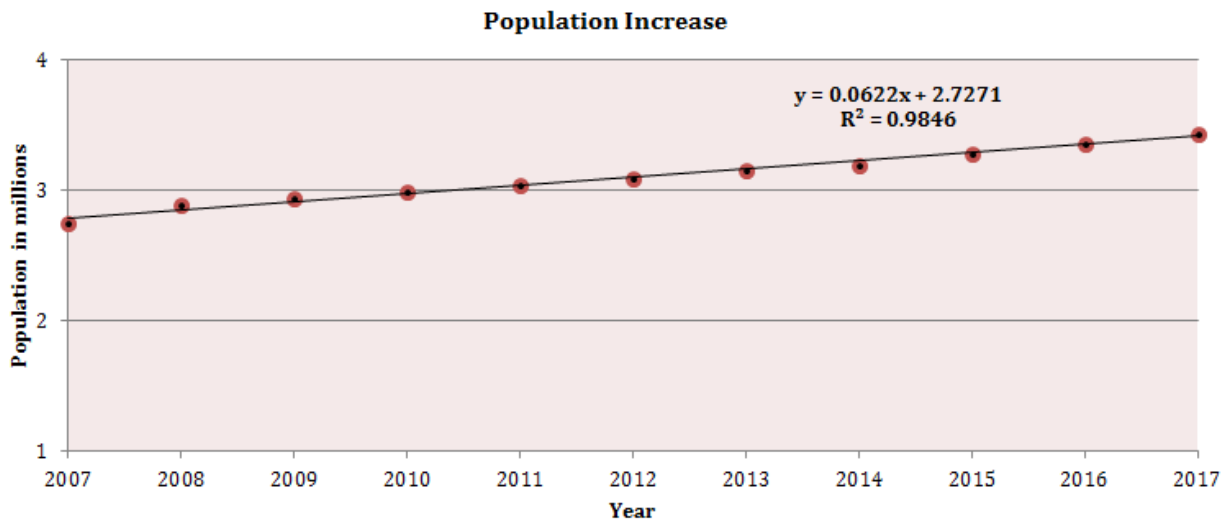


Figure 4-6: Population data of Addis Ababa

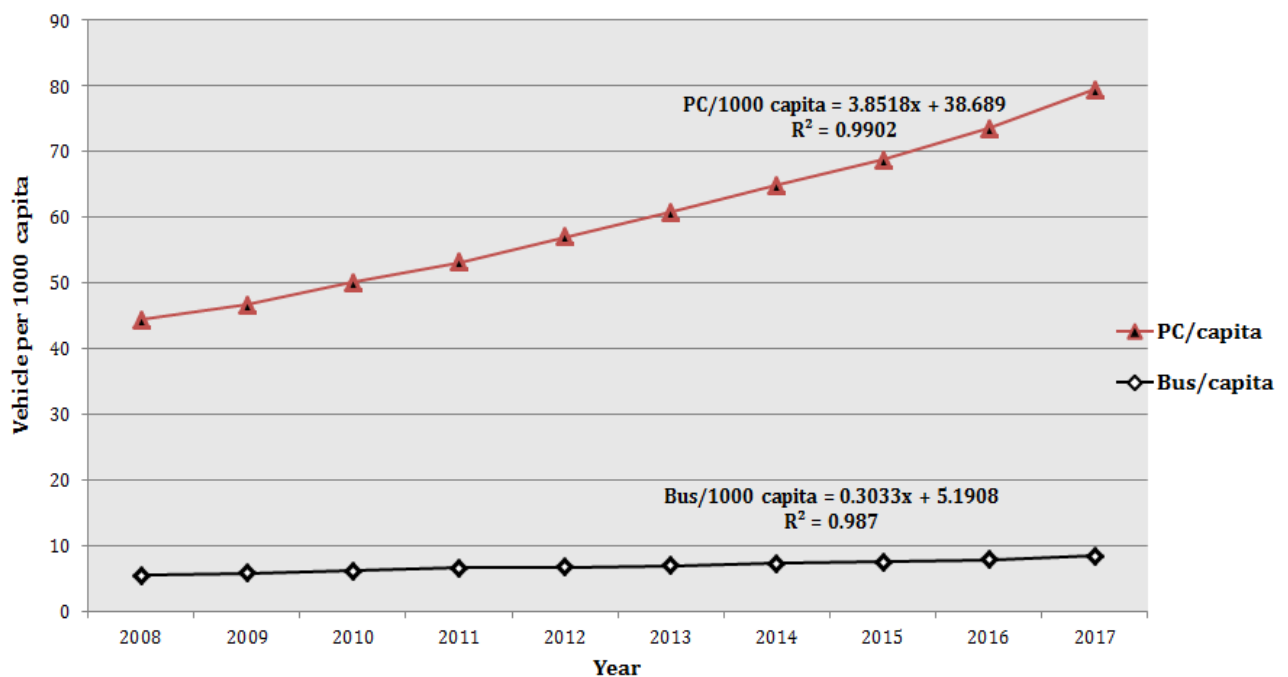


Figure 4-7: Trend of change in number of vehicles per capita

Examining the trend of change in the number of vehicles per unit of road network length

The last factor considered is the total length of the road network, which is presented here. The road network length shows relatively a higher increase starting from 2012. Overall there has been an increase in the total road network, which is due to the budget allocation to road construction attributed to the government’s policy to increase the accessibility through road transportation and the construction of new highways and bypasses in an attempt to reduce traffic congestions. But care should be given to analogous growth of public transportation system as large budget allocations to road construction without comparable allocation to the development of the public transportation system could lead to negative indication of sustainable growth.

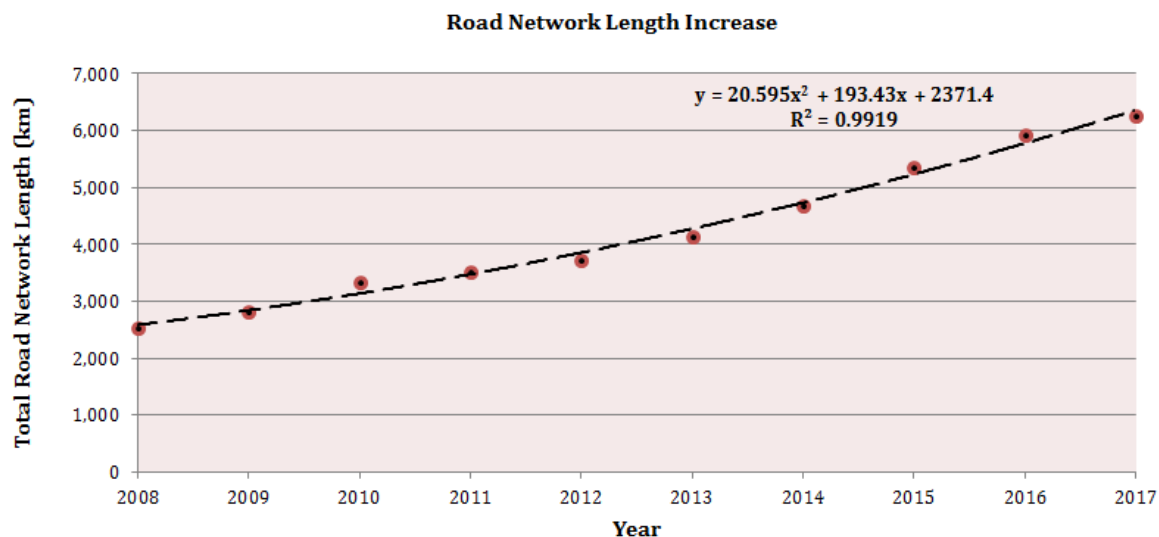


Figure 4-8: Total road network length over time

The trends for the number of vehicles per unit length of the road network, for the two types of vehicles considered, are shown on next page. Generally it is noticed that the number of vehicles per unit length of the road network decrease due to the considerable increase in the road network length. The level of investment allocated to road construction with limited allocation to public transportation is another indication of the lack of consideration for the sustainability of the transportation system in Addis Ababa.

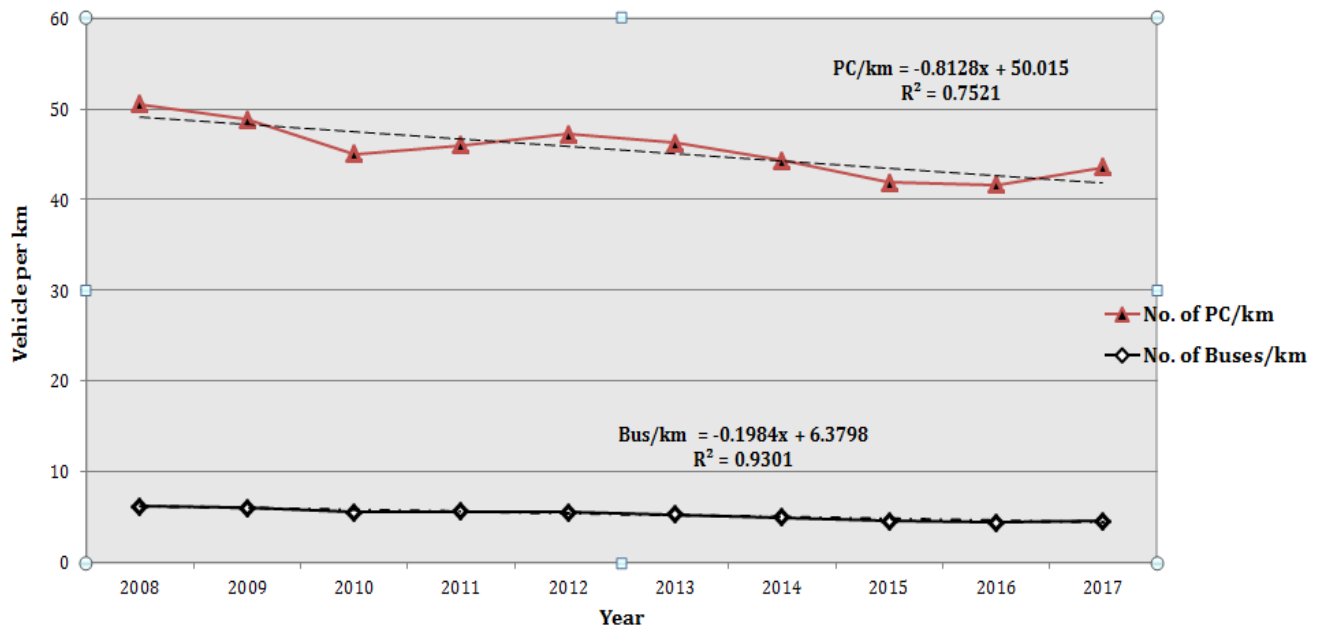


Figure 4-9: Trends for the number of vehicles per unit length of the road network

4.6. Discussion on Trend Analysis

Most of the trends indicate that the current growth trends of traffic in Addis Ababa are unsustainable. The results show that the traffic growth is mainly due to increases in the private cars as compared to public transport modes, the rate of increase for buses is very small, which is a negative indication regarding the traffic growth. The trend analysis presented an evaluation of the traffic growth in relative to time, population and road network length. The analyses exposed that the current trend of traffic growth is unsustainable as it is directed more towards an increase in the use of private transportation. Also, the level of investment in road construction is very good and there has been a significant increase in the total road network length over the past few years. However, the level of investment in public transportation does not match with that level for road construction.

The rate of increase in vehicle population results in a decreased rate of urban mobility. The traffic development in Addis results in high rate of traffic accidents and pollution. Congestion occurred regularly, as there is an imbalance between the current vehicles volume (high traffic volume) and road capacity, fixed work schedule, unavailability of enough public transport, and poor land-use planning. The rise in Automobile ownership with the poor condition of the roads has resulted in the high level of traffic safety and congestion problems.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Within the framework of this paper, the sustainable mobility conditions of Addis Ababa city were evaluated using a representative selection of indicators. The selection was based on the review of international literature as well as the knowledge of the specific local characteristics obtained through observations and discussion with concerned governmental bodies. The assessment of indicators highlighted the lack of reliability and consistency in the available data and the necessity of conducting own measurements to bridge essential gaps.

The evaluation of mobility condition in terms of sustainability indicates weak level and highlights the necessity of taking measures. In specific, looking through average scores of the indicators those concerning the sustainability of the public transport system are ranked to the lowest score. Integration in public transportation is recommended as a viable instrument for providing high quality and seamless urban transport and enhancing sustainable urban development. Moreover, the synthetic analysis of all indicator categories suggests that focus should be also given on the available infrastructure for active transport. Current urban mobility patterns are also having considerable negative impacts on air quality, noise pollution, safety and usage of public space.

Non-motorized transport (NMT), particularly walking, is the dominant mode yet receives very little attention; Addis lack adequate sidewalks, or signalized and safe intersections, and accessibility to public transport stations is inadequate. Road intersections and pedestrian pathways (where they exist) are often usurped by motorists using the space as parking, or by street vendors using the space for trading. In addition, it is often reported that cycling is regarded as socially unacceptable.

The evaluation of the traffic growth in Addis Ababa relative to time, population and road network length showed that the current trend is unsustainable as it is directed more towards an increase in the use of private transportation. In addition, the level of investment in road construction is very good and there has been a significant increase in the total road network length over the past few years. However, the level of investment in public transportation does not match with that level for road construction.

Based on the analyses conducted in this research and the available literature review, it is recommended to the government to consider the following:

- Make the transport systems more efficient through
 - The development of safe pedestrian areas and transport policies acknowledging the dominance of walking and cycling, specific actions aimed at “giving back” space to the NMT users. Improve the layout and maintenance of public space in urban areas, with the aim of promoting safer and more dignified travel conditions for pedestrians.
 - Allocate more funding for the development of PT systems along with consideration of the level of population and economic growth in the country. Strategies adopted for transportation systems management, must focus more on the provision of transit systems that are better than the private cars in terms of travel time and travel costs.
 - Minimize the need for individual motorized travel through adequate land-use and transport planning and management to promote PT and NMT modes.
 - Integrate transport infrastructure and services right from planning to operating and maintenance. Road based public transport requires stations easily accessible from both the roadside and the pedestrian pathways.
- Reduce pollution through car ownership control and / or limitations to car use
 - Apply more strict requirements for registering private transportation vehicles. Urban sprawl is behind the continuous growth of motorized transport, where walking and cycling are not feasible options. Inadequate vehicle maintenance, poor fuel quality and aging vehicle fleets bring with them increased air and noise pollution.
 - Gather sufficient and updated information to draft appropriate legislations and guidelines for dissemination of more fuel-efficient vehicles and assess the impact of vehicle emission and fuel quality on the ambient air quality.

Finally, the paucity of time series and comprehensive data are major obstacles for urban transport research undertakings in many cities in the developing Countries. This research is of no different; to overcome these problems an extensive study was done on previous works. It is highly recommended that Addis should establish a practice of conducting citywide and detailed household travel surveys and documenting traffic-related data properly to provide easy access for those who need them for further research.

RESEARCH REFERENCE

- (UN-Habitat), U. N. (2017). *The State of Addis Ababa 2017, The Addis we want*. United Nations Human Settlements Programme (UN-Habitat).
- Aklilu, A., & Necha, T. (2018, Feb). Analysis of the Spatial Accessibility of Addis Ababa's Light Rail Transit: The Case of East–West Corridor. *Urban Rail Transit*, 4(1), pp 35–48.
- Alonso, A., Monzón, A., & Cascajo, R. (2015). Comparative analysis of passenger transport sustainability in European cities. *Ecological Indicators*, 48, pp. 578-592.
- Buzási, A., & Csete, M. (2015). Sustainability Indicators in Assessing Urban Transport Systems. *Periodica Polytechnica Transportation Engineering*, 43(3), pp 138-145.
- Carruthers, R., Dick, M., & Saurkar, A. (2005). *Affordability of Public transport in Developing Countries, Transport Papers*. Washington: The World Bank Group.
- Castillo, H., & Pitfield, D. E. (2010). ELASTIC – A methodological framework for identifying and selecting sustainable transport indicators. *Transportation Research Part D: Transport and Environment*, 15(4), pp 179-188.
- Cavalcanti, C. d., Limont, M., Dziedzic, M., & Fernandes, V. (2017). Sustainability assessment methodology of urban mobility projects. *land use policy*, 60, pp 334-342.
- Cavalcanti, C. d., Limont, M., Dziedzic, M., & Fernandes, V. (2017). Sustainability assessment methodology of urban mobility projects. *land use policy*, 60, pp 334-342.
- CSA. (2013). *Federal democratic republic of Ethiopia population projection of Ethiopia for all regions at wereda level from 2014 –2017* . Addis Ababa.
- CSA. (2014). *The Federal Democratic Republic of Ethiopia, Statical report on 2013 natonal labor force survey*. Addis Ababa.
- Demdime, F. T. (2012). *Integrating Public Transport Networks and Built Environment: The case of Addis Ababa and experiences from Stockholm*. Master Thesis in Environmental

- Engineering and Sustainable Infrastructure* . Stockholm: KTH-Royal Institute of Technology School of Architecture and the Built Environment.
- Dobranskyte-Niskota, A., Perujo, A., & Pregl, M. (2007). *Indicators to Assess Sustainability of Transport Activities– Part 1: Review of the Existing Transport Sustainability Indicator Initiatives and Development of an Indicator Set to Assess Transport Sustainability Performance*. European Commission JRC/ Scientific and Technical Research series – ISSN 1018-5593, ISBN 978-92-79-07802-6, Institute for Environment and Sustainability.
- EEA. (2002). *Are we moving in the right direction? Indicators on transport and environment integration in the EU. TERM 2000*. Environmental issues series No 12, European Environment Agency, Copenhagen, Denmark.
- Failler, P., Karani, P., & Seide, W. (2016). *Assessment of the Environment Pollution and its impact on Economic Cooperation and Integration Initiatives of the IGAD Region; National Environment Pollution Report – Ethiopia*. Technical Report .
- Gilbert, R., Irwin, N., Hollingworth, B., & Blais, P. (2002). Sustainable Transportation Performance Indicators (STPI).
- Gössling, S. (2013). Urban transport transitions: Copenhagen, City of Cyclists. *Journal of Transport Geography*, 33, pp. 196-206.
- Group, W. B. (2015). *City Strength, Resilient cities Program for Enhancing Urban Resilience: Addis Ababa, Ethiopia*. Global Practice on Social Rural and Resilience, World Bank Group.
- Gudmundsson, H. (2017, March 2-3). Refined Sustainable Urban Transport Index for cities in Asia. *Regional Meeting on Sustainable Urban Transport Index*. jakarta, Indonesia: CONCITO.
- Haghshenas, H., & Vaziri, M. (2012). Urban sustainable indicators for global comparison. *Ecological Indicators*, 15(1), pp 115-121.

- Haghshenas, H., & Vaziri, M. (2012, September 19). Urban Sustainable Transportation Indicators for Global Comparison. *Ecological Indicators*, 15, pp 115-121.
- Hussen., B. W. (2017). *Sustaining Sustainable Mobility : the Integration of Multimodal Public Transportation in Addis Ababa*. Lyon: History. Université de Lyon.
- Kenea, K., Kinnear, S., & Akbar, D. (2017). Accessibility Of Anbessa City Bus Service In Addis Ababa, Ethiopia:An analysis of stakeholder's opinons. *Australasian Journal of Regional Studies*, 23(1).
- Kupiszewska, D. (1997). *Modelling for Sustainable Cities: The Transport Sector*. Working Paper 521, Institute of Transport Studies,University of Leeds, Leeds, UK.
- Litman, T. (2013, June). The New Transportation Planning Paradigm. *ITE Journal* (www.ite.org), Vol. 83, pp. 20-28.
- Litman, T. (2018). *Well Measured: Developing Indicators for Sustainable and Livable Transport Planning*. Victoria Transport Policy Institute.
- Litman, T., & Burwell, D. (2006). Issues in Sustainable Transportation. *International Journal of Global Environmental Issues*, 6(4), pp 331-347.
- Minken, H., Jonsson, D., Shepherd, S., Järvi, T., May, T., Page, M., et al. (2003). Developing Sustainable Land Use and Transport Strategies: A Methodological Guidebook. European Commission, Fifth Framework—EESD. Retrieved from http://www.ivv.tuwien.ac.at/projects/prospects/Deliverables/pr_del14mg.pdf.
- Miranda, H., & Rodrigues da Silva, A. (2012). Benchmarking sustainable urban mobility: The case of Curitiba, Brazil. *Transport Policy*, 21, pp. 141-151.
- Nallet, C. (2018). *The Challenge of Urban Mobility: A Case Study of Addis Ababa Light Rail, Ethiopia*. Notes de l'Ifri, Ifri.
- OECD. (1999). *Indicators for the Integration of Environmental Concerns into Transport Policies*. Organisation for Economic Cooperation and Development, Paris, France.

- Rodrigues da Silva, A. N., Costa, M. d., & Ramos, R. A. (2010). DEVELOPMENT AND APPLICATION OF I_SUM - AN INDEX OF SUSTAINABLE URBAN MOBILITY. *TRB*.
- Shiau, T., & Liu, J. (2013). Developing an indicator system for local governments to evaluate transport sustainability strategies. *Ecological Indicators* 34, pp. 361-371.
- Singh, R. K., Murty, H. R., Gupta, S. K., & & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological indicators*. 9(2), pp 189-212.
- Tanguay, G. A., Rajaonson, J., Lefebvre, J. F., & Lanoie, P. (2010). Measuring the sustainability of cities: An analysis of the use of local indicators. *10*(2), pp 407-418.
- Tesfaye, H. (2014). *Transport Accessibility for People with Physical Impairment in Addis Ababa*. Addis Ababa Univerisity, Graduate School of Social Work.
- Tilahun, R. A. (2017). *EVALUATION OF THE TRANSPORTATION SYSTEM FOR DISABLES VERSUS POLICY IMPLEMENTATION IN ADDIS ABABA CITY*. Addis Ababa, Ethiopia: A Thesis in Road And Transportation Engineering Stream.
- Török, Á. (2014). Environmental comparism of road and railway transport: a case study in Hungary. *IJTTE.*, 4(2), pp. 210-219.
- Tóth-Szabó, Z., & Várhelyi, A. (2012). Indicator Framework for Measuring Sustainability of Transport in the City . *Procedia - Social and Behavioral Sciences*, 48, pp. 2035-2047.
- UITP, & UATP. (2010). *Report on Statistical Indicators of Public Transport Performance in Africa. Version 1.3-Final version*. Trans Africa.
- UN-HABITA. (2010/11). *State of the World Cities : Bridging the Urban Divide*.
- WBCSD. (2016). *Methodology and Indicator Calculation Method for Sustainable Urban Mobility*. World Business Council for Sustainable Development, Sustainable Mobility Project 2.0 (SMP2.0), Indicators Work Stream - 2nd Edition -ISBN: 978-2-940521-26-5, Switzerland.

- Wolde, M. (2016). *An Overview of Addis Ababa Transport System: Implication to Air pollution*. Project Submitted to Addis Ababa University Civil Engineering Department in partial fulfillment of the requirement for the Degree of Degree of Master of Engineering in Civil Engineering, Addis Ababa.
- Wolde, M. (2016). *An Overview of Addis Ababa Transport System: Implication to Air Pollution*. Addis Ababa, Ethiopia: Project thesis Submitted to Addis Ababa University Civil Engineering.
- Zegras, C. (2006, July). Sustainable Transport Indicators and Assessment Methodologies. *Biannual Conference and Exhibit of the Clean Air Initiative for Latin American Cities, Sao Paulo, Brazil*, p. Available from: <http://www.seedengr.com/Sustainability%20and%20Transportation%20indicators%20and%20Assessment%20Methodologies.pdf>.
- Zheng, J., Garrick, N. W., Atkinson-Palombo, C., McCahill, C., & Marshall, W. (2013). Guidelines on Developing Performance Metrics for Evaluating Transportation Sustainability. *Research in Transportation Business & Management*, 7, pp 4-13.
- Zito, P., & Salvo, G. (2011). Toward an urban transport sustainability index: an European comparison. *European Transport Research Review*, 3(4), pp. 179-195.

APPENDIXES

Appendix 1: Indicator selection process Snapshot

a. Preliminary/ initial long list

1. Preliminary/initial long listing	
Transport sustainability aims, objectives and indicators : sources (kupszewska 1997)	
Aims and objectives	Indicators
Environment and resources	
Improvement of air quality	Emissions and/or concentrations of NO, VOC, SO ₂ , CO, PM ₁₀ .
Reduction of noise pollution	Noise levels; % of population affected by high noise levels.
Reduction of resource use including energy sources, space, raw materials	Fuel consumption; Use of space by transport infrastructure; Use of raw materials is evaluated indirectly by the number of cars and the length of roads. Further research required for more detailed modelling.
Reduction of environmental impact including :Contribution to global warming, Solid waste production, Influence on water system, Impact on animals and vegetation, Soil pollution	Per capita CO ₂ emissions; Number of scrapped cars/year, % of metal parts, tyres, oil, batteries recycled; Impact on water system, fauna and flora is evaluated qualitatively. Modelling possible, but further research required.
Quality of life	
Increasing accessibility and freedom of mode choice	Accessibility to jobs, shopping and leisure centres, by mode (expressed as time , cost and generalised cost)
Safety improvement	Accidents/casualties/ pedestrian fatalities
Increasing quality of public transport (density, frequency, speed, comfort information)	Evaluated qualitatively, with some quantitative indicators (e.g. distance from public transport, frequency, speed)
Minimising severance and improving livability of residential streets	Severance is evaluated indirectly by traffic flow (veh./h) and speed. Research to develop a severance index is needed
Minimising aesthetic impairment and negative impact on our heritage	% of 10-11 years old children accompanied school (indicates not only severance but also size of catchment areas, crime level, etc.)
Intra-generational equity (e.g. improving accessibility for those without a car)	Distribution of benefits and negative impacts by social group, age, sex and/or geographical area
Public participation in policy making	Public participation is evaluated qualitatively
Intermediate objectives and operational/substitute indicators	
Demand reduction/total traffic restraint	Traffic volume in veh.-lans (per capita?); Trip rates by purpose; Car occupancy
Shorter passenger trips	Average trip length by purpose; Availability of local services (shopping, education, sport and leisure)
Shorter freight trips	% of consumed goods produced locally
Reduction of congestion	Ratio of peak hour and off-peak speeds
Control of motorisation level	Total number of cars; Number of passenger cars per 1000 people
Reduction of traffic in sensitive areas (city centre, residential areas)	Geographical distribution of traffic volume (veh.-lans)
Shift to less environmentally-damaging modes	Modal share (for passenger transport); % of long distance goods transport by rail; Length of traffic-free routes for cyclists and walkers
Traffic calming	Speeds (geographical distribution); % of roads length in residential areas with traffic calming
Increased use of technological improvements	Percentage of cars with catalytic converters; Percentage of cars with an access to driver information systems
Economic performance	
Economic efficiency	Net Present Value
Balance of all (internal and external, including environmental impacts) costs, and revenues. Difficult to do, further research highly recommended.	

b. Grouping and identifying the overlapping indicators

2. Procedure for grouping and identifying overlapping indicators		
		Indicators
Environment and resources	Improvement of air quality	Emissions and/or concentrations of NO, VOC, SO ₂ , CO, PM ₁₀ .
Environment and resources	Reduction of noise pollution	Noise levels; % of population affected by high noise levels.
Environment and resources	Reduction of resource use including energy sources, space, raw materials	Fuel consumption Use of space by transport infrastructure Use of raw materials is evaluated indirectly by the number of cars and the length of roads. Further research required for more detailed modelling.
Environment and resources	Reduction of environmental impact including :Contribution to global warming, Solid waste production, Influence on water system, Impact on animals and vegetation, Soil pollution	Per capita CO ₂ emissions Number of scrapped cars/year, % of metal parts, tyres, oil, batteries recycled Impact on water system, fauna and flora is evaluated qualitatively.
Quality of life	Increasing accessibility and freedom of mode choice	Accessibility to jobs, shopping and leisure centres, by mode (expressed as time , cost and generalised cost)
Quality of life	Increasing accessibility and freedom of mode choice	% of households with an access to a car (including neighbourhood street fleet/local rental schemes)
Quality of life	Safety improvement	Accidents/casualties/ pedestrian fatalities
Quality of life	Increasing quality of public transport (density, frequency, speed,	Evaluated qualitatively, with some quantitative indicators (e.g. distance from public transport, frequency, speed)
Quality of life	Minimising severance and improving livability of residential streets	Severance is evaluated indirectly, by traffic flow (veh./h) and speed. severance index is needed
Quality of life	Minimising severance and improving livability of residential street	% of 10-11 years old children accompanied school (indicates not only severance but also size of catchment areas, crime
Quality of life	Minimising aesthetic impairment and negative impact on built her	Aesthetic /built heritage impacts are evaluated qualitatively
Quality of life	Intra-generational equity (e.g. improving accessibility for those w	Distribution of benefits and negative impacts by social group, age, sex and/or geographical area
Quality of life	Public participation in policy making	Public participation is evaluated qualitatively
Intermediate objectives and operational su	Demand reduction/total traffic restraint	Traffic volume in veh.-lans (per capita?) Trip rates by purpose Car occupancy
Intermediate objectives and operational su	Shorter passenger trips	Average trip length by purpose Availability of local services (shopping, education, sport and leisure)

c. Categorizing and merging coinciding indicators

2.1. Categorizing and merging coinciding indicators			
		Indicators	Dimension
Improvement of air quality	Air pollution	Emissions and/or concentrations of NO, VOC, SO ₂ , CO, PM ₁₀ .	Environment and resources
Reduction of environmental impact including :Contribution to global warming, Solid waste production, Influence on water system, Impact on animals and vegetation, Soil pollution	Air pollution and waste	Per capita CO ₂ emissions Number of scrapped cars/year, % of metal parts, tyres, oil, batteries recycled Impact on water system, fauna and flora is evaluated qualitatively.	Environment and resources
Theme 2> INTERACTIONS WITH THE ENVIRONMENT	Air pollution	Transport emissions and emission intensities...	ENVIRONMENTAL
Theme 2> INTERACTIONS WITH THE ENVIRONMENT	Air pollution	Population exposed to air pollution from transport....	ENVIRONMENTAL
Theme 2> INTERACTIONS WITH THE ENVIRONMENT	Water pollution	Oil released from marine transport	ENVIRONMENTAL
Theme 2> INTERACTIONS WITH THE ENVIRONMENT	Waste	Transport-related waste and related recovery rates...	ENVIRONMENTAL
Theme 2> INTERACTIONS WITH THE ENVIRONMENT	Waste	Hazardous waste imported or exported .	ENVIRONMENTAL
Environmental consequences of transport	Air pollution	Transport emissions of greenhouse gasses (CO ₂ and N ₂ O) by mode	ENVIRONMENTAL
Environmental consequences of transport	Air pollution	Transport emissions for air pollutants (NO _x , MNVOCs, PM ₁₀ , SO _x , total ozone precursors) by mode	ENVIRONMENTAL
Environmental consequences of transport	Environmental consequences of transport	Population exposed to exceedances of EU air quality standards for PM ₁₀ , NO ₂ , benzene, ozone, lead and CO Exceedances of air-quality objectives	ENVIRONMENTAL
Environmental consequences of transport	waste	Waste from road vehicles (end-of-life vehicles)	ENVIRONMENTAL
Environmental consequences of transport	waste	Waste from road vehicles (number and treatment of used tires)	ENVIRONMENTAL
Technology and utilization efficiency	Transport Emissions	Emissions per passenger-km and emissions per tonne km for CO ₂ , NO _x , NMVOC, PM, SO _x by mode	ENVIRONMENTAL
Technology and utilization efficiency	Technology and utilization efficiency	Uptake of cleaner fuels (unleaded petrol, electric, alternative fuels) and numbers of alternative-fuelled vehicles	ENVIRONMENTAL
Technology and utilization efficiency	Transport Emissions	Proportion of vehicle fleet meeting certain air and noise emission standards (by mode)	ENVIRONMENTAL
	Transport Emissions	32. NO _x emissions (per capita)	ENVIRONMENTAL
	Transport Emissions	33. VOCs emissions (per capita)	ENVIRONMENTAL
	Transport Emissions	34. PM ₁₀ and PM _{2.5} emissions (per capita)	ENVIRONMENTAL
	Transport Emissions	35. SO _x emissions (per capita)	ENVIRONMENTAL
	Transport Emissions	36. O ₃ concentration (per capita)	ENVIRONMENTAL

d. Categorizing and merging coinciding indicators: full list of 70 suggested indicators

2.2. Categorizing and merging coinciding indicators: full list of 70 suggested indicators			
		Indicators	Dimension
Protection of the Environment			
Reduce local and regional pollution	Transport emissions and emission intensities...	Transport emissions of greenhouse gasses (GHG) by mode, total vehicle emissions	ENVIRONMENTAL
	Transport emissions and emission intensities...	Emitted GHG by freight transport	ENVIRONMENTAL
Improvement of air quality	Transport emissions and emission intensities...	Share of zero-emission modes in modal split	ENVIRONMENTAL
INTERACTIONS WITH THE ENVIRONMENT	Air pollution exposure	Population exposed to air pollution from transport....	ENVIRONMENTAL
	Air pollution exposure	Population exposed to exceedances of air quality standards and objectives	ENVIRONMENTAL
	Air pollution exposure	Number of days of exposure per year	ENVIRONMENTAL
	Embodied emissions	Emissions from vehicle and facility construction	ENVIRONMENTAL
Reduction of air pollutant emissions through infrastructure use		Existence of features that promote the reduction of air pollutant emissions by motor vehicles using the infrastructure	
Reduction of environmental impact including :Contribution to global warming, Solid waste production, Influence on water system, Impact on animals and vegetation, Soil pollution	Environmental consequence of transport; Air pollution and waste	Climate change emission, Per capita CO ₂ emissions Number of scrapped cars/year, % of metal parts, tyres, oil, batteries recycled(end of life vehicles and number/treatment of used tires....) Impact on water system, fauna and flora evaluated qualitatively. Habitat and ecosystem disruption	Environment and resources
Technology and utilization efficiency		Proportion of vehicle fleet meeting certain air and noise emission standards (by mode)	ENVIRONMENTAL
Technology and utilization efficiency		Uptake of cleaner fuels (unleaded petrol, electric, alternative fuels) and numbers of alternative-fuelled vehicles	ENVIRONMENTAL
Reduction of noise pollution	Traffic noise/ Noise pollution	Noise levels; % of population affected by high noise levels, Population exposed to transport noise ≥ 65db(A) ..	Environment and resources
	Environmental consequences of transport, Exposure and	% of population exposed to and annoyed by traffic noise, by	



e. Candidate indicators filtered by scope and score for methodological quality and relevance

3. Candidate indicators Filtered by scope and score for methodological quality and relevance							
	Indicators	Methodological quality				Relevance to ST	Score
		Data availability	Data quality	Data validity	Analytical soundness		
Protection of the Environment							
Transport emissions and emission intensities...	Transport emissions of greenhouse gasses (GHG) by mode, total vehicle emissions	2	3	2	2	1	10
Transport emissions and emission intensities...	Share of zero-emission modes in modal split	3	3	2	1	1	10
Air pollution exposure	Population exposed to air pollution from transport.....	3	3	3	2	1	12
Embodied emissions	Emissions from vehicle and facility construction	2	3	2	2	2	11
Reduction of air pollutant emissions through infrastructure use	Existence of features that promote the reduction of air pollutant emissions by motor vehicles using the infrastructure	2	2	2	2	2	10
Technology and utilization efficiency	Proportion of vehicle fleet meeting certain air and noise emission standards (by mode)	1	2	1	1	1	6
Technology and utilization efficiency	Uptake of cleaner fuels (unleaded petrol, electric, alternative fuels) and numbers of alternative-fuelled vehicles	2	2	2	2	2	10
Traffic noise/ Noise pollution	Noise levels; % of population affected by high noise levels, Population exposed to transport noise $\geq 65\text{db(A)}$..	3	2	3	2	2	12
Livable streets and neighborhoods							
Environmental consequences of transport, Land use impacts	Land take by transport infrastructure, Change in land use by transport infrastructure, sprawl	1	2	1	1	1	6
Environmental consequences of transport, Infrastructure	Fragmentation of ecosystems and habitats/ Proximity of transport infrastructure to desined	2	2	2	2	2	10

f. Final indicators edited and refined

3.2. Candidate indicators Filtered by scope and score for methodological quality and relevance			
	Indicators	Score	Final indicators/ Edited and refined
Environmental consequences of transport, Land use impacts	Land take by transport infrastructure	6	Road density per land take, public transport infrastructure density.
Supply of transport infrastructure and services	Capacity of transport infrastructure networks, by mode and by type of infrastructure	6	Road and rail network length and density per population, length of cycling and walking paths per population, PT network length per population, PT size per population
Transport infrastructure cost	Investments in transport infrastructure/ per capita by mode/ as share of	6	Transport infrastructure cost
Supply of transport infrastructure and services	Road quality - paved roads, fair/ good condition	6	Road quality
Accessibility for all/Universal accessibility	Quality of transport for disadvantaged people (disabled, low incomes, children), Access to essential services near the roadways of people with special needs or mobility restrictions	6	Accessibility for all
Accessibility to public transportation	Average distance between public transportation stop points	7	Accessibility to public transportation
Transportation Risk and Safety	Accidents/casualties/pedestrian fatalities; Vulnerable road user accidents, Police-reported crashes	6	Road safety no of acc/population, no of acc per vulnerable road users
Control of motorization level	Total number of cars, Number of passenger cars per 1000people, Motorized traffic volume	6	motorized traffic volume increase
Shift to less environmentally-damaging modes	Length of traffic-free routes for cyclists and walkers	6	pedestrian infrastructure density, cycling infrastructure density
Traffic calming	% of roads length in residential areas with traffic calming	6	Share of traffic calming roads
	Share of public transport in modal split	7	Share of PT
Vehicles and mobile equipment	Road vehicle stocks, Size of vehicle fleet (vehicle/ 1 mln. inhabitants) Density of vehicles registered	7	vehicle ownership
Technology Status	Average age of the vehicle fleet	7	Age of vehicle fleet
Technology Status	Proportion of PT fleet meeting certain air emission standards	7	Proportion of PT vehicle fleet meeting certain air emission standards
Energy use	Energy consumption by the road transport sector,	7	Total energy consumption per capital (Consumption of road fuels)
Affordability	All residents can afford access to basic services and activities	7	Availability and quality of affordable transport modes (walking, cycling and PT)

Population data										
Year	1961	1967	1984	1994	2007	2013	2014	2015	2016	2017
Population data	443,728	1,167,315	1,423,111	2,112,737	2,739,551	3,156,057	3,195,000	3,273,000	3,352,000	3,433,999
Population in million	0.444	1.167	1.423	2.113	2.740	3.156	3.195	3.273	3.352	3.434
	A	B	C	D	E	F				
1	m_n	m_{n-1}	...	m_2	m_1	b	0.050084339	-97.67892647		
2	se_n	se_{n-1}	...	se_2	se_1	se_b	0.002585329	5.167818724		
3	r_2	se_v					0.979128324	0.164967485		
4	F	d_f					375.2945739	8		
5	ss_{reg}	ss_{resid}					10.21336832	0.21771417		
Equation:							y = 0.05x - 97.679			
The standard error values for the coefficient:							Estimated population			
The standard error value for the constant b:							2008 2.890			
The coefficient of determination:							2009 2.941			
The F statistic, or the F-observed value:							2010 2.991			
The degrees of freedom:							2011 3.041			
The degrees of freedom:							2012 3.091			
Significance level:							Alpha value 0.05			
Critical value in F- distribution table:							F-critical			
Probability that F value occurred by chance:							F-probability 5.23294E-08			
Year										
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PC registered	128,140	137,371	149,909	161,636	176,296	191,718	207,468	224,997	246,460	272,720
BUS registered	15,788	16,903	18,416	19,892	20,806	21,917	23,335	24,549	26,095	28,901
Population (in 1000)	2,890	2,941	2,991	3,041	3,091	3,156	3,195	3,273	3,352	3,434
PC/1000capital	44	47	50	53	57	61	65	69	74	79
Bus/1000capital	5	6	6	7	7	7	7	8	8	8
	A	B	C	D	E	F	PC/1000capital		Bus/1000capital	
1	m_n	m_{n-1}	...	m_2	m_1	b	3.851837389	-7691.948535	0.30334453	-603.6217
2	se_n	se_{n-1}	...	se_2	se_1	se_b	0.135692631	273.0816977	0.01229853	24.7508208
3	r_2	se_v					0.990169487	1.232489526	0.98702072	0.11170696
4	F	d_f					805.7927645	8	608.367191	8
5	ss_{reg}	ss_{resid}					1224.02373	12.15224344	7.59147704	0.09982757
Equation.....							PC/1000capital = 3.8518x - 7691.949		Bus/1000capital = 0.3033x - 603.623	
The standard error values for the coefficient:							sem 0.135692631		sem 0.01229853	
The standard error value for the constant b:							seb 273.0816977		seb 24.7508208	
The coefficient of determination:							r2 0.990169487		r2 0.98702072	
The F statistic, or the F-observed value:							F-statics 805.7927645		F-statics 608.367191	
The degrees of freedom:							v1 1		v1 1	
The degrees of freedom:							v2 8		v2 8	
Significance level:							Alpha value 0.05		Alpha value 0.05	
Critical value in F- distribution table:							F-critical		F-critical	
Probability that F value occurred by chance:							F-probability 2.56376E-09		F-probability 7.8006E-09	
Year										
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PC registered	128,140	137,371	149,909	161,636	176,296	191,718	207,468	224,997	246,460	272,720
BUS registered	15,788	16,903	18,416	19,892	20,806	21,917	23,335	24,549	26,095	28,901
GDP/capita	987.25	1,146.54	1,331.93	1,537.91	1,800.53	2,099.58	2,442.57	2,777.51	3,232.10	3,727.46
PC/unit GDP	130	120	113	105	98	91	85	81	76	73
Bus/unit GDP	16	15	14	13	12	10	10	9	8	8
	A	B	C	D	E	F	PC/unit GDP		Bus/unit GDP	
1	m_n	m_{n-1}	...	m_2	m_1	b	-6.299381754	12774.69083	-0.95168689	1926.64076
2	se_n	se_{n-1}	...	se_2	se_1	se_b	0.307155796	618.1516691	0.03993838	80.3760626
3	r_2	se_v					0.981334964	2.789881064	0.98610667	0.36275831
4	F	d_f					420.6088696	8	567.815674	8
5	ss_{reg}	ss_{resid}					3273.782365	62.26749081	74.720904	1.05274873
Equation.....							PC/unit GDP = -6.299x + 12774.69		Bus/unit GDP = -0.952x + 1926.641	
The standard error values for the coefficient:							sem 0.307155796		sem 0.03993838	
The standard error value for the constant b:							seb 618.1516691		seb 80.3760626	
The coefficient of determination:							r2 0.981334964		r2 0.98610667	
The F statistic, or the F-observed value:							F-statics 420.6088696		F-statics 567.815674	
The degrees of freedom:							v1 1		v1 1	
The degrees of freedom:							v2 8		v2 8	
Significance level:							Alpha value 0.05		Alpha value 0.05	
Critical value in F- distribution table:							F-critical		F-critical	
Probability that F value occurred by chance:							F-probability 3.34381E-08		F-probability 1.0245E-08	

Increase in road network length											
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
	4032064	4036081	4040100	4044121	4048144	4052169	4056196	4060225	4064256	4068289	
Road network length	2,537	2,814	3,325	3,512	3,731	4,148	4,679	5,365	5,915	6,256	
	A	B	C	D	E	F	Road Network Length		Road Network Length		
1	m_n	m_{n-1}	...	m_2	m_1	b	419.9757576	-840973.0121	20.59469697	-82473.6795	82570598
2	se_n	se_{n-1}	...	se_2	se_1	se_b	22.82852918	45942.46177	5.698190661	22935.2219	23078534
3	r_2	se_v					0.976908544	207.3504134	0.991943296	130.934453	#N/A
4	F	d_f					338.4484907	8	430.9208025	7	#N/A
5	ss_{reg}	ss_{resid}					14551320.05	343953.5515	14775266.78	120006.817	#N/A
Equation.....							$y= 419.97x-840973.0121$	or	$y=20.595x^2-82473.6795x$		
The standard error values for the coefficient:							sem	22.82852918			
The standard error value for the constant b:							seb	45942.46177			
The coefficient of determination:							r2	0.976908544			
The F statistic, or the F-observed value:							F-statics	338.4484907			
The degrees of freedom:							v1	1			
The degrees of freedom:							v2	8			
Significance level:							Alpha value	0.05			
Critical value in F- distribution table:							F-critical				
Probability that F value occurred by chance:							F-probability	7.8472E-08			
No. of PC and Buses per km											
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
PC registered	128,140	137,371	149,909	161,636	176,296	191,718	207,468	224,997	246,460	272,720	
BUS registered	15,788	16,903	18,416	19,892	20,806	21,917	23,335	24,549	26,095	28,901	
Total Road Network	2,537	2,814	3,325	3,512	3,731	4,148	4,679	5,365	5,915	6,256	
No. of PC/km	51	49	45	46	47	46	44	42	42	44	
No. of Buses/km	6	6	6	6	6	5	5	5	4	5	
	A	B	C	D	E	F	No. of PC/km		No. of Buses/km		
1	m_n	m_{n-1}	...	m_2	m_1	b	-0.812770376	1681.244814	-0.19838558	404.539686	
2	se_n	se_{n-1}	...	se_2	se_1	se_b	0.164968075	331.9985887	0.01922197	38.684258	
3	r_2	se_v					0.752120121	1.49839695	0.93014218	0.17459223	
4	F	d_f					24.27369661	8	106.518321	8	
5	ss_{reg}	ss_{resid}					54.49914393	17.96154737	3.24693908	0.24385958	
Equation.....							No. of PC/km= $-0.813x+1681.245$		No. of Buses/km= $-0.198x+404.539$ 		
The standard error values for the coefficient:							sem	0.164968075	sem	0.01922197	
The standard error value for the constant b:							seb	331.9985887	seb	38.684258	
The coefficient of determination:							r2	0.752120121	r2	0.93014218	
The F statistic, or the F-observed value:							F-statics	24.27369661	F-statics	106.518321	
The degrees of freedom:							v1	1	v1	1	
The degrees of freedom:							v2	8	v2	8	
Significance level:							Alpha value	0.05	Alpha value	0.05	
Critical value in F- distribution table:							F-critical		F-critical		
Probability that F value occurred by chance:							F-probability	0.001154031	F-probability	6.7024E-06	