The Development of a Metric for the Accessibility and Affordability of Transport in South Africa

by

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Abstract

Accessibility and affordability of transport have a major impact on the people living in a country. Accessibility is defined as the ease with which people are able to reach activities or destinations (Litman, 2010a), whilst transport affordability is defined as the ability to purchase access (Litman, 2010b). In South Africa, the way in which accessibility and affordability of transport are currently measured is insufficient, as people's needs are not taken into consideration. In this project, the objective is to develop metric, a standard of measurement, which quantifies the performance of these aspects within the transport system. The Nelson Mandela Bay Metropolitan is used as the study area since it is relatively isolated, providing a relevant representation of reality. The various factors that affect accessibility and affordability are researched in order to understand what impact these factors have on the transport system. Previous measures that have been used to assess accessibility and affordability in other countries, are taken into account when designing the metric. Data is gathered from a variety of sources, predominantly surveys carried out by Statistics South Africa. Using a synthetic population and a multi-agent transport simulation toolkit (MATSim), the transport system is simulated and used to test the feasibility of the metric. The development of a metric is a benefit to the government as it assists in the planning and assessing of the transport system in South Africa, as well as enabling the testing of strategies that will assist in uplifting the poor.

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Chapter 1

Introduction

People cannot interact with others and participate in activities if these cannot be accessed, and transport is one method that allows people to gain access to their required destinations. However, transport is not an ideal system as yet and there is still much room for improvement to make it accessible and affordable for all people.

South Africa, a developing country, still has major problems concerning accessibility and affordability of transport. The poorest fifth of households use 21% of their income for transport, whilst high-income households use 12-16% of their income. This high percentage makes the poor very vulnerable to variations in transportation costs. Increasing transportation costs have a significant negative effect on low-income households, thus compromising their ability to improve their living conditions (Venter, 2011).

The Gini index is a measurement of the extent to which the distribution of income of individuals and households differs within an economy from an ideal distribution. An index of 0 indicates that the income distribution of the economy is perfectly equal amoungst the population, whilst an index of 100 indicates maximum inequality. The last reading that was taken in South Africa was in 2011, which indicated a Gini index of 63.1 (The World Bank, 2012). This is one of the worst readings worldwide, indicating an immense gap between the rich and the poor. By having a transport system that is inaccessible and unaffordable, the problem is only aggravated.

To analyse transport, one needs to look at more than just time, distance and cost of travelling. Transport improvements are limited to vehicle travel conditions or mobility, limiting the improvements that can be made to the transport system. If vehicle travel conditions are the focus, then roads and congestion can be improved. If mobility is the focus, then public transport can be improved. However, if accessibility is the focus, the above two factors will be considered, as well as other factors such as improving land use patterns, walking and cycling conditions as well as delivery services Litman (2010a).

1.1 Defining Accessibility and Affordability

Accessibility and affordability are two terms that describe aspects of the transport system, but which have different definitions. Although often used interchangeably, distinctive definitions are provided in this project. The definitions that are used to define accessibility and affordability in the context of this report, are stated below.

1.1.1 Defining Accessibility

Transport has traditionally been evaluated from a mobility-oriented analysis, which can also be described as the distance or the time that a vehicle travels. Accessibility-based analysis is now becoming the more appropriate method to use because it focuses less on the quality and quantity of travel, and more on the needs of the household (Litman, 2010a). Mobility refers to the performance of the transport, such as the distance travelled and the speed of the transport. The downfalls of focusing on mobility, and not on accessibility, are that people are more susceptible to vehicle failures and fluctuations in vehicle costs and fuel prices (Litman, 2010b). The increase in vehicle use also places a larger burden on the roads as congestion levels rise. Therefore, when evaluating transport it is important to understand what the meaning of accessibility is. Accessibility has been defined by various authors, as listed in Table 1.1.

Table 1.1: Definitions of accessibility.

Definition	**Source**
"The calculation of accessibilities requires information about the activity opportunities, population, and information about the generalised cost of travel between any two points."	Axhausen et al. (2011)
"The ease of reaching desired destinations given a number of available opportunities and intrinsic impedance to the resources used to travel from the origin to the destination."	Bocarejo and Oviedo (2012)
"The ability to fulfill basic needs by accessing various daily destinations."	Fan and Huang (2011)
"The opportunities available to individuals and companies to reach those places in which they carry out their activities."	Gutirrez (2009)
"The ease with which activity sites can be reached for goods, services, employment, education, and recreation."	Knowles (2009)
"The ease of reaching goods, services, activities and destinations, which together are called opportunities."	Litman (2010a)

There is a discrepancy in the above definitions, since accessibility is referred to as either the ability to access or as the ease to access. A person may have the capability to walk to their destination, however, it may not be an easy or convenient option. Accessibility looks at the bigger picture in terms of the ease with which a person is able to gain access to transport, and not only their physical travel movements. Therefore, the needs and the circumstances of the person are taken into consideration, making accessibility more focused on the amount of trips that a person needs to make to reach their destination, and not on the distance travelled. Accessibility is defined as stated by Litman (2010a), which is defined in Table 1.1. This definition mentions opportunities, which are potential activities that can be reached and activities that have already been reached. The degree to which a person is able to access transport, as well as the future options of access, are taken into account.

1.1.2 Defining Affordability

Traditionally, affordability is measured as the amount of household income or expenditure that goes towards transportation, the financial burden transport places on a household, or simply put, the cost of travel. These measures are very broad and do not consider the variation of people's needs. This makes it difficult to set a standard measure of affordability that is relevant to all people's transport needs (Fan and Huang, 2011). It has been noted by Venter and Behrens (2005) that current measures do not take into account that the perception of affordability is different for each household. There are various definitions that have been defined in recent research, which are provided in Table 1.2.

Table 1.2: Definitions of affordability.

Definition	**Source**
"The ability to make necessary journeys to work, school, health and other social services, and make visits to other family members or urgent other journeys without having to curtail other essential activities."	Carruthers et al. (2005)
"To be able to do or spare something, especially without incurring financial difficulties or without risk of undesirable consequences."	Collins English Dictionary (2012)
"Affordability refers to people's ability to purchase important goods and services."	Fan and Huang (2011)
"Affordability refers to people's ability to purchase basic goods and services... Transportation affordability means that people can purchase access to basic goods and activities."	Litman (2010b)

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There may be slight confusion in the actual definition of affordability; some sources refer to it as the ability to purchase and other sources refer to it as the ability to perform a task. From the above definitions, the words "ability", "important goods" and "necessary journeys" implies that affordability is needs-oriented. Fan and Huang (2011) state that

> "making transportation affordable is not merely about maintaining a low cost of travel, but also about when, where, and how transportation assistance could be adequately provided to meet people's desire of accessing destinations."

Affordability is defined as stated by Litman (2010b), which is defined in Table 1.2. This definition focuses on purchasing access, thereby taking accessibility into consideration.

1.2 Current State in South Africa

The South African Department of Transport has indicated that transport is affordable, as long as the percentage of transport expenditure does not exceed 10% of the household's income (Venter and Behrens, 2005). This benchmark is unrealistic because the current expenditure is between 12% and 21%. The problem with this benchmark is that each person has different needs, therefore a common level cannot be used for all people ranging from low-income households to high-income households.

South Africa is facing problems of increasing energy prices, highlighting the issue of affordability of transport in terms of reducing the cost of living (Venter, 2011). The World Bank has investigated the way in which transport can assist in reducing poverty, and it was found that transport affordability does not directly cause unemployment. The reason being that low-income households are more likely to choose to live in areas that are less accessible and have less affordable transport, but are more affordable in terms of housing costs. Therefore, transport inaccessibility and unaffordability is a symptom of poverty and not the cause.

Transport has an indirect effect on unemployment levels, as it affects economic growth. By implementing transport policies and promoting growth in the transport sector, transport alleviates poverty by contributing to economic growth. Transport can assist in increasing employment levels by directly providing access and creating jobs by building transport infrastructure (Gannon and Liu, 1997). This emphasises that the inability to access and afford transport is detrimental to a country. Unemployment levels cannot be decreased if there is no economic growth. Therefore, for South Africa to alleviate poverty and create an environment of economic growth, it is of utmost importance to focus on making transport easily accessible and affordable to low-income households.

The layout of residential and commercial areas in South Africa has resulted in low-income households having to travel much longer distances from outlying areas to reach the city, than households from the suburban areas. The layout resulted during Apartheid when non-white people were relocated to settlements outside the cities, far removed from work opportunities. The trend of people flocking to remote settlements, removed from the place of work, has increased in the post-Apartheid years, exacerbating the problem.

Several studies have investigated the trade-offs between housing and travel costs, and it is becoming clear that low cost housing often has high associated transport costs, which results in no affordability gain (Lipman, 2006). Housing and transport costs are rising faster than incomes, further contributing to the unaffordability of transport. Venter and Behrens (2005) found that in South Africa, more than half of the poorest people have to walk long distances to their destinations because they cannot afford transport. Low-income households often have to purchase a car because public transport is inadequate, which places a large burden on these households. If affordable houses are only available on the outskirts of cities, the roads leading to the cities will become heavily congested. This congestion will increase commute times and reduce road quality, driving up the cost of transport (Lipman, 2006).

A study by Venter (2011) was carried out to determine the affordability of transport, providing a basis to understanding where South Africa lies in terms of the transport that is being used by various income groups. Factors including distance travelled, transport mode used (public or private transport) and income were investigated in order to identify the different type of commuters. The average trip cost for each type of commuter was identified, providing an understanding of the travel behaviour and demographics of commuter types. The result was that there are many types of commuters in South Africa, with no one type being significantly more predominant than the others. The main types of commuters are: short-distance walkers (17%), low-income public transport users (17%), medium-income public transport users (17%) and medium-income car drivers (15%). Low-income households either walk or use public transport, whilst high-income households drive cars. Further results can be viewed in the table in Appendix A.

1.3 Benefits of Measuring Accessibility and Affordability

To measure the accessibility and affordability of transport, it needs to be established what is *acceptable* and what is not. It will be beneficial to have a tool that measures accessibility and affordability because it will allow for a benchmark to be determined, as well as to evaluate strategies.

There are various types of strategies that have been investigated and that have been found to improve accessibility and affordability (Litman, 2010b). These include:

- Encouraging walking and cycling as an alternative transport, e.g. build walking and cycling paths.
- Improving access to schools such as school buses.
- Improving public transport and making it more readily available.
- Improving security to encourage walking and cycling.
- Incentives to increase use of other modes of transport other than cars.
- Subsidies for public transport and car sharing.
- Developing areas that have accessible transport.

It is important to understand the hurdles in order to put strategies into effect that will improve conditions. If strategies are implemented correctly, the accessibility and affordability of transport will be improved.

1.4 Research Problem

The way in which accessibility and affordability is measured in South Africa is insufficient. South Africans and the areas that they live in are very diverse. In order to understand and quantify these differences, a measurement of accessibility and affordability is required, giving an accurate reflection of what different people's transport needs are, based on their individual circumstances. The aim of this project is therefore to:

> develop a tool that measures the accessibility and affordability of transport, taking the South African environment and the needs of the people into consideration.

1.5 Research Design and Methodology

A metric, which is a standard of measurement that quantifies performance (Oxford English Dictionary, 2012), is required to measure accessibility and affordability of transport in South Africa. In this case, the quantified performance is the degree to which transport is accessible and affordable.

The Nelson Mandela Bay Metropolitan is used as an area of research, since it is a small community that is relatively isolated. This makes the building of a model based on the area simpler and a convenient reflection of reality. A synthetic population of Nelson Mandela Bay Metropolitan has been built. This model is used to simulate the transport system of Nelson Mandela Bay Metropolitan, using MATSim, which is a multi-agent transport simulation toolkit. An agent (a simulated person) can be followed from their house to various facilities, including work, schools, shopping centres and healthcare. Data about the times, distances, speeds and routes that the agent travels is available. The model is used to test the validity of the metric and provide results for the accessibility and affordability of transport for the Nelson Mandela Bay Metropolitan.

1.6 Document Structure

The current literature is investigated to determine the factors and methods used to assess accessibility and affordability in Chapter 2. Chapter 3 focuses on determining where data is available on the factors that are relevant in developing the metric, as well as collecting the data. Chapter 4 provides an overview of the method that is used to develop the metric. Chapter 5 focuses on the design of the accessibility matrices and the results when measuring the accessibility of the synthesised population of Nelson Mandela Bay Metropolitan. The design of the affordability ratios and the results thereof are discussed in Chapter 6. The final conclusions and recommendations of the project are made in Chapter 7.

Chapter 2

Literature Review

As a first step towards the metric's development, this chapter reviews the factors affecting accessibility and affordability, as well as the methods previously used to evaluate these aspects.

2.1 Factors Affecting Accessibility and Affordability

Litman (2010a) states that "evaluating accessibility requires detailed understanding of people's needs and abilities, travel mode constraints, and the quality of service at a destination." This statement highlights the importance of identifying the factors that affect accessibility and affordability in order to improve the transport system.

The following factors have been identified as affecting accessibility and demonstrate the importance of understanding the reasons for people's behaviour (Litman, 2010a).

Transportation Demand This looks at the various reasons for the need of transport. The aspects that are considered include: demographics of commuter, purpose of trip, destination, mode of transport, the number of trips required, distance travelled and the time of day.

Mobility The distance, time and speed of trips fall under mobility. Each mode of transport travels at a different speed and distance. If mobility is increased, it leads to increased accessibility, as more destinations can be reached if a person is travelling faster. Congestion affects mobility of certain modes of transport such as cars, buses and taxi's.

Transportation Options The quality and quantity of transport modes that are available in an area affect accessibility. If only one mode of transport is available, transport accessibility is not very high in that area.

Security Lack of security in an area constrains the use of a facility. For example, if a transit station is located in an area with inadequate security, the access is limited since commuters will be too scared to risk using the transport.

Information The information available to people plays a large role in accessibility. For a person to use public transport, they need to know the schedules, routes and tariffs. It is also important for people to have sufficient information about their destinations. For example, a shop within walking distance is much more accessible than a shop that a person needs a vehicle to reach. Improving access and accuracy of information about transport and destinations is an easy and cost-effective way to improve accessibility.

Integration Integration of transport is a factor that is often problematic in terms of the ease of transferring between different modes of transport. For example, train and bus stations are sometimes difficult to access due to their locations. At many stations, the parking facilities are inadequate due to availability, price and convenience, which affect the use of this mode of transport.

Roadway Design and Management This factor looks at available infrastructure and quality of the roads. Congestion and poor quality roads affect accessibility negatively. For example, a person may struggle to drive on a road with potholes, and therefore would have to take a longer alternative route.

When evaluating accessibility, all travel links including delays, actual travel distances and any associated travel costs need to be considered. The associated travel costs are the point where accessibility and affordability are inter-linked. Transport affordability can be evaluated in terms of quality, cost of using various modes of transport, cost of housing and the portion of budget that is spent on transport.

A person's needs determine the mode of transport that they require and the amount of trips that they need to make on a daily basis. Litman (2010b) lists the following factors that should be considered when evaluating affordability:

- Ability to drive.
- Ability to use affordable modes such as walking, cycling and public transport.
- Daily activities, which includes the amount of time spent travelling.
- Income.

Transport costs comprise of public transport costs, car expenses, fuel and car purchases. Transport costs can force people to exceed their monthly budgets in terms of time and money, which is a difficult burden for low-income households to bear. People that own their own cars are affected differently by affordability than people who use public transport. People who use public transport have to pay transit or taxi fares, which are cheaper than car expenses, making public transport more affordable. The further a person has to travel, the more expensive the transport. By increasing the affordability of transport, the disposable income of a household is increased, allowing people to travel further or spend more money, on for instance education. It is also a way to increase economic development, as it is easier for people to access jobs (Litman, 2010b).

Land use is an important factor that affects both accessibility and affordability. A household's travel patterns can be viewed as a triangle between home, work and services. By improving the variety of services within an area, such as shops, schools and the number of transport modes travelling to work areas, transport accessibility and affordability can be improved (Litman, 2010a). The more destinations are concentrated, the better their accessibility, as can be seen in Figure 2.1. This is an example of a household that lives within 3 km of all needs-oriented destinations. It demonstrates an activity chain of a mother who takes the children to school and then goes to work. Throughout the day, various chores are completed at different destinations.

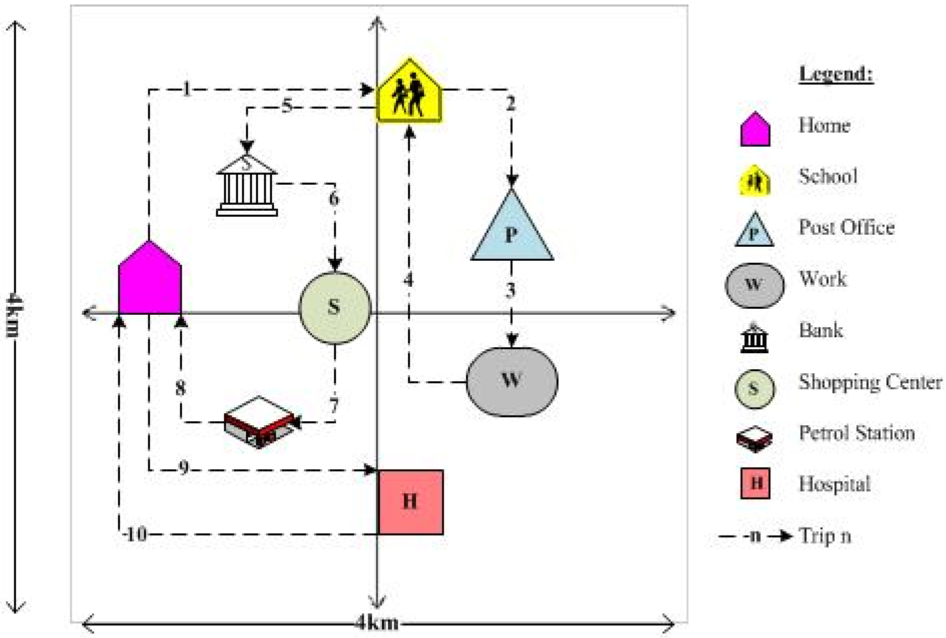


Figure 2.1: Densely located destinations, adapted from (Litman, 2010a).

Table 2.1 shows from where each trip originates and ends, demonstrating the movement between destinations indicated by the numbered lines in Figure 2.1.

Table 2.1: Activity chain destinations.

Trip Number (n)	From	To
1	Home	School
2	School	Post Office
3	Post Office	Work
4	Work	School
5	School	Bank
6	Bank	Shopping Centre
7	Shopping Centre	Petrol Station
8	Petrol Station	Home
9	Home	Hospital
10	Hospital	Home

It can be seen that it is easy to access a variety of destinations. The shorter the distance between destinations, the easier it is to access these destinations, especially if they are close enough to walk or cycle to. Therefore, the cost of travelling between destinations in terms of money and time is minimized.

People have different perspectives and needs, and this must be accounted for when planning and evaluating accessibility and affordability. People should be categorized according to their demographics and needs, in order to understand how they are affected by transport.

2.2 Existing Methods to Evaluate Accessibility and Affordability

Transport affordability should not only be assessed by looking at the expenditures of a household, since the cause of the unaffordability is different for each household (Venter, 2011). Therefore, it is necessary to use various methods to determine the needs of the households in terms of transport modes used, number of trips and the preference of the person.

According to Fan and Huang (2011), there are two main types of measures being used to categorize affordability. The first type, Equation (2.1), looks at the proportion of disposable income spent on transport whilst the second type, Equation (2.2), looks at the proportion of transport expenditure by a household. To make use of these two measures, a benchmark first needs to be established to determine the acceptable level of affordability. A single benchmark is too simplistic to apply to an entire population and does not consider the transportation needs of the commuters fully (Venter and Behrens, 2005). Another problem with these two measures is that they are too focused on financial ability and mobility. Their usefulness is limited because they do not take into account the differences in income, family structure and accessibility, or consider the time that commuters spend travelling (Fan and Huang, 2011). Accessibility should be incorporated into the measurement of affordability, taking into account the ability to purchase access to transport.

$$\text{TA Index} = \frac{\text{Transportation Expenditure}}{\text{Household Income After Tax}} \times 100\% \tag{2.1}$$

$$\text{TA Index} = \frac{\text{Transportation Expenditure}}{\text{Total Household Expenditure}} \times 100\% \tag{2.2}$$

Accessibility can be measured in travel time, the number of trips to reach a destination and travel costs (Litman, 2010a). However, constraints, such as traffic congestion, and a household's financial ability also need to be considered. The number of trips refers to how many different transport modes are used to reach the desired destination. For example, if travelling by train, a person would have to walk to the train, ride the train and finally walk to their destination. This person takes three trips to reach their destination. All the factors that affect accessibility cannot all be measured in a single evaluation method, since there are too many different aspects. There are accessibility-based models available that take mobility and land use into account. These models make use of geographic information systems (GIS) to measure distances between various locations. However, these models do not take other factors, such as comfort, security and user availability, into account. Therefore other models need to be used in conjunction to fully evaluate accessibility.

Individual transport accessibility profiles assist in understanding how each mode of transport has different requirements in order to be accessible. Table 2.2 demonstrates the main accessibility profiles.

Table 2.2: Comparison of transportation modes (VTPI, 2006).

Mode	**Speed**	**User Cost**	**User Requirements**	**Facilities**
Walking	Low	Low	Physical Ability	Walkways
Cycling	Medium	Low	Physical Ability	Paths / roads
Intercity Bus and Rail	High	Medium	Minimal	Roads/rails
Taxi	High	High	Minimal	Roadways
Private Automobile	High	High	License	Roadways

Litman (2010a) proposes a rating system to evaluate accessibility, using a transportation depravation index, to identify if a person is transportation disadvantaged. There are five factors listed, namely, vehicle accessibility, physical ability, poverty, commute responsibility and dependencies. Each factor is assigned a certain number of points. A person is given a rating for each factor depending on the degree to which they are affected by the factor. If a person scores between 10 and 20, they are moderately disadvantaged by transport, and if they score above 20, they are severely disadvantaged. This index assists in determining what people's transport needs and problems are.

Four points have been defined by Litman (2010b) that assist in detecting the unaffordability of transport. These include:

1. Examine the cost of travel in terms of actual cost and compared to the household's income.

2. Examine the travel behaviour to detect where unaffordability is affecting travel options.

3. Evaluate people's perceptions of affordability problems.

4. Compare the above results to determine where the affordability problems lie.

The housing plus transportation index is another measure of affordability. This index sums the housing and transport costs and then divides the total by the household income (Fan and Huang, 2011). Although the index allows for a measurement of affordability, it is limited to use in policy decisions because it does not reflect the transportation needs of commuters. However, this index does indicate that in order to improve land use policies, it is important to consider housing and transport costs in unison, since there is often a trade-off between the two.

Lipman (2006) conducted a study to compare what households spend on housing and transport, as well as to determine the trade-offs between housing and transport. This study measures the combined burden of household and transport costs on households, and aims to give a true indication of the cost. A problem that households are encountering is that affordable housing is only available far from employment areas. Households then spend money on travelling to work, which they cannot really afford. The study compares household and transportation costs of households with different incomes and living locations. The study provided results on which neighbourhoods were spending the most money on housing and transport, as well as which neighbourhoods had the least amount of transport options. The following steps are followed in the study:

1. Determine the average percentage spent on housing and transport according to area. This comparison between housing and transport costs demonstrates the trade-off.

2. Determine the combined percentage of income that is spent on housing and transport. This gives a better indication of the affordability of transport.

3. The comparisons are then grouped according to different income groups. For each income group, the housing and transport percentages are compared in the central city, near other employment centres and away from employment centres. This indicates the burden that is being placed on different income households in different areas.

4. A 2x2 matrix is set up with four types of neighbourhoods. The neighbourhoods are categorized according their housing and transport expenditure.

5. For each type of neighbourhood, a demographic profile is set up to understand which people are experiencing what kind of cost burdens.

6. For each type of neighbourhood, the average time, distance and speed is categorised according to private and public transport.

The method that is used in this study is useful to gain a better understanding of affordability. It takes more than just the cost of transport into consideration, which is important when evaluating affordability. By creating a demographic profile of the neighbourhood, the transport needs of these people become more apparent, and the transport system can be understood in terms of accessibility and affordability.

Fan and Huang (2011) developed a framework, which is population-sensitive, to better measure affordability. The framework provides a foundation for transport policies by indicating what transport options are applicable to which households and circumstances. Therefore, affordability is redefined as the capacity of a household to be able to pay transportation costs within an acceptable time limit, without incurring a financial burden. The framework considers the fact that different households have different needs. The transportation needs of a household are a reflection of the characteristics of a household, such as a single-mother household compared to a household of an unmarried woman with no children. The households have different needs in terms of travel time, destination and the mode of transport, and these factors need to be taken into consideration when measuring affordability.

Figure 2.2 describes the relationship between the affordability factors that are used in the development of the framework. Socio-demographics determine how much income and time a household has available. Accessibility is used to determine the effects of the built environment on the quantity and the price of transport. The location of the desired destination and the mode of transport used, affects the price of transportation.

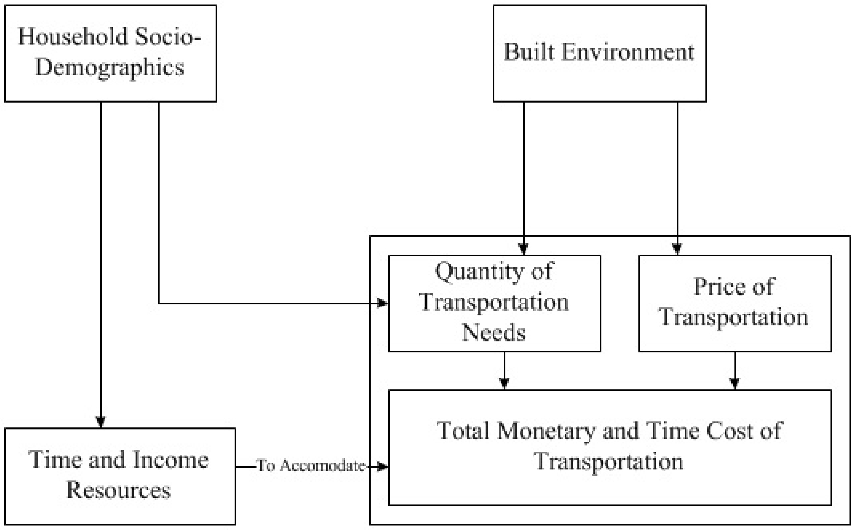


Figure 2.2: Factors in the development of affordability matrix, adapted from Fan and Huang (2011).

The framework determines the affordability of a household using a matrix with monetary and time thresholds. The following steps are followed to develop the framework:

1. Identify attributes that affect affordability.
2. Categorize attributes according to household socio-demographics, built environment and policy environment.
3. Classify population groups according to the amount of time and income available to spend on transport.
4. Identify factors that affect the built environment and the policy environment, such as policies. Policies directly affect transport costs and indirectly affect the built environment.
5. Develop a population-and location-based evaluation matrix. This matrix categorises the population according to socio-demographics and measures the accessibility with regard to basic activities, public transport and subsidies.
6. Establish two affordability thresholds; Equation (2.3) takes the cost of transport into account, and Equation (2.4) takes the travel time into account.

$$\text{TA Index} = \frac{\text{Needs-oriented transportation expenditure}}{\text{Household disposable income}} \times 100\% \tag{2.3}$$

$$\text{TA Index} = \frac{\text{Needs-oriented travel time}}{\text{Household disposable time}} \times 100\% \tag{2.4}$$

7. Collect data about the population in terms of time spent on daily activities, income, transport policies such as subsidies, the public transport available and the access to transport.
8. Using the collected data, calculate thresholds for each population group and use these to determine the transport affordability of each type of population group.

2.3 Synthetic Population

In the synthetic population of Nelson Mandela Bay Metropolitan, each person, known as an agent, has their own profile and needs. From the literature review, it can be seen that the synthetic population can be linked to the factors that affect accessibility and affordability. An agent can be tracked and factors such as the delays, travel distances, travel costs and mode of travel can be assessed. Therefore, the individual needs of a person can be simulated, making the evaluation of these factors possible for purposes of the metric.

2.4 Main Findings from the Literature Review

The factors that have been identified as relevant in the development of the metric include:

- Socio-demographics of households.
- Household income including data about government grants.
- Transport costs including fuel costs, and toll charges.
- Public transport including modes, routes and stations.
- Layout of area and location of residential and commercial areas.
- Time usage on activities such as transport.

Methods to develop the metric have been identified, allowing for the development of a metric that is suitable to the South African environment. The metric is predominantly based on the work done by Fan and Huang (2011) and Lipman (2006). The metric measures the accessibility and affordability of various demographic groups, as done by matrix of Fan and Huang (2011). Therefore, the metric takes into consideration the different needs of households based on time and income. The method used by Lipman (2006) is taken into consideration when designing the affordability aspect of the metric. This method looks at various factors that affect the affordability, especially the trade-offs between housing and transport costs. These two methods result in a clear picture of the state of accessibility and affordability of transport in South Africa.

Chapter 3

Data Collection

To compile the metric, a variety of data sources are used. In the first section of this chapter, the available sources are reviewed. The second section looks at the specific sources that are used for the components of the proposed metric.

3.1 Sources of Data

Various sources are available that validate the choice of factors in that there is sufficient data available on each factor to develop the metric. This section reviews the possible sources that can be used.

3.1.1 Socio-demographics of Households

The socio-demographics looks at the characteristics of the people living in the household. This assists in understanding the needs of households. Data is available from the Census of 2001, the Community Survey of 2007 and the Household Travel Survey of 2003. Figure 3.1 shows the data available from each survey.

The Census of 2001 This survey was conducted in October 2001 by Statistics South Africa. The purpose of the Census was to gather data about the people living in South Africa and it was to be used for the planning of providing for the needs of South Africans.

The Community Survey of 2007 This survey was conducted in February 2007 by Statistics South Africa. It was designed to bridge the gap of information between the 2001 Census and the 2011 Census. The survey aimed to gather information at a district and municipal level. The factors that are investigated in the survey include population dynamics, living conditions and housing (Statistics South Africa, 2008a). The results of the 2011 will only be made public at the end of 2012.

The National Household Travel Survey of 2003 This survey was initiated in September 2002 and published in 2003. The survey is a study of how households and individuals travel during a certain time period. The survey was conducted in South Africa for the purpose of collecting data to assist in research, planning and the development of policies. The main objectives of the survey were to understand the transport needs of households, assess attitudes towards transport, determine the costs of transport and assist in developing subsidies for public transport (Department of Transport, 2005).

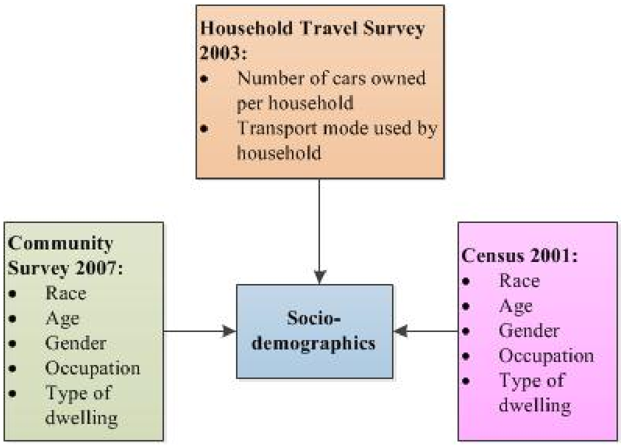


Figure 3.1: Data available for socio-demographics.

3.1.2 Household Income

The disposable income of a household assists in understanding what a household can afford. The disposable income is necessary in order to calculate the ratio that determines affordability. Different households have different types of incomes, indicating the different needs of households. Data is available about household income from the Census of 2001, the Community Survey of 2007 and the National Household Income and Expenditure Survey of 2006. Figure 3.2 shows the data available from each survey.

The National Household Income and Expenditure Survey of 2006 This survey was conducted between September 2005 and August 2006. The main purpose of the survey was to assist in the development of the Consumer Price Index. The survey was also used to study the extent of poverty and the inequality of the distribution of income in South Africa (Statistics South Africa, 2008b).

The government provides grants to people in South Africa who are in need of income. The Community Survey of 2007 provides data on the type of income that a household is receiving, which provides understanding into what type of transport the household can afford.

There are various sources of income. These include:

- Wage/salary.
- Earnings from own business.
- State grant.
- Private pension.
- Unemployment insurance fund.
- Investment.
- Money from other household members.

- Remittances from outside.
- Other: rental, interest etc.

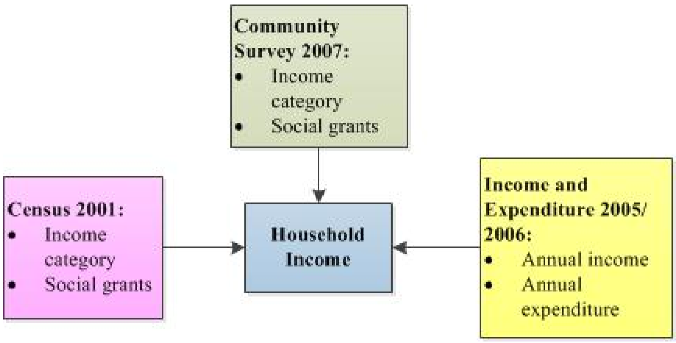


Figure 3.2: Data available for household income.

3.1.3 Transport Costs

It is necessary to know what the transport costs of a household are in order to determine if these costs are affordable in terms of their income. This factor looks at transport expenditure of income, as well as private transport costs, and therefore includes data about fuel costs and toll gates. Data is available from the National Household Travel Survey of 2003, the Nelson Mandela Bay Metropolitan Travel Survey of 2004 and the Income and Expenditure Survey of 2005/2006. Figure 3.3 shows the data available from each survey.

The Nelson Mandela Bay Metropolitan Travel Survey of 2004 This survey was of a randomly selected 1% sample of the population living in the metropolitan (Nelson Mandela Bay Municipality, 2006). The results were to be used to forecast the demand for public transport in order to provide strategies for the improvement of transport. The result of the survey provided information about people's daily travel behaviour.

South African National Roads Agency (SANRAL) SANRAL, which is the South African National Roads Agency, has data available about the prices and location of toll gates. They are responsible for maintaining the national road network in South Africa. The funds required to develop new infrastructure, as well as to maintain the current infrastructure are collected using toll gates (SANRAL, 2012).

Automobile Association (AA) Fuel is a major contributing factor to transport costs. Increases in fuel price lead to increased transport costs. The AA provides up to date data about the fuel prices and the running costs of cars (The Automobile Association, 2012).

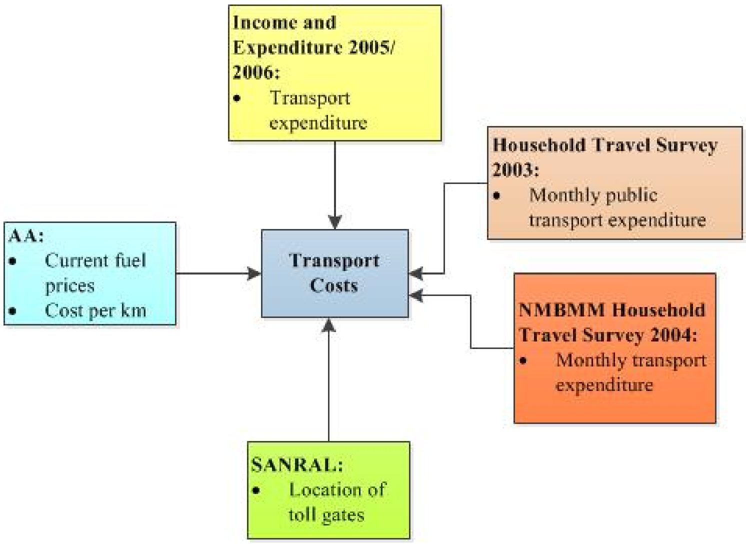


Figure 3.3: Data available for transport costs.

3.1.4 Public Transport

It is necessary to understand what types of public transport are available, the cost and the routes. This assists in determining the need for public transport.

The Nelson Mandela Bay Metropolitan Travel Survey of 2004 and the National Household Travel Survey of 2003 provide data about public transport, including the type of transport that people use. Figure 3.4 shows the data available from each survey.

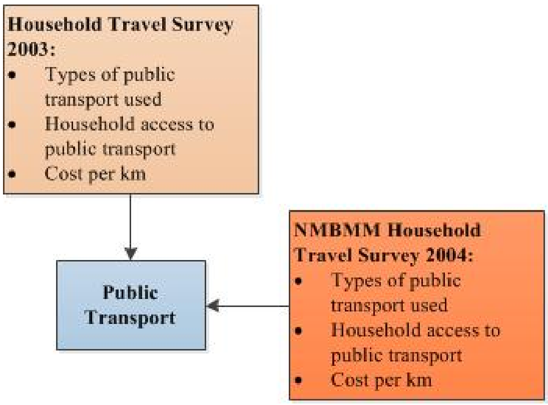


Figure 3.4: Data available for public transport.

3.1.5 Layout of Area

Data is required about where the different areas including residential, commercial, industrial and retail areas lie in order to know where people are travelling to, and what routes they are using. The layout of the area can be used to calculate travel distances and travel times. Figure 3.5 shows the data that is available.

OpenStreetMap This map provides detail on the layout of Nelson Mandela Bay Metropolitan. On OpenStreetMap, various areas and roads can be viewed, including the locations of housing areas, schools and shopping centres.

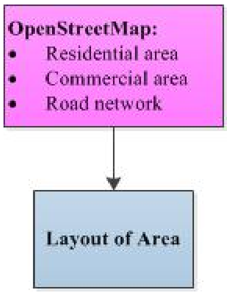


Figure 3.5: Data available for area layout.

3.1.6 Time Usage

Data is required that estimates the time that is spent travelling to destinations on a daily basis. This provides insight into how much travelling costs a household in terms of time. Data about time usage is available from the Nelson Mandela Bay Metropolitan Travel Survey of 2004. Data includes the mode of transport and the time it takes for people to travel between various locations. Data is also available from the Survey of Time Use of 2001. Figure 3.6 shows the data available from each survey.

Survey of Time Use of 2001 Statistics South Africa conducted the survey during February, June and October 2000 as a study of how people use their time. The two objectives of the survey were to gather information for the development of policies, as well as to gain insight into work-related activities (Statistics South Africa, 2001). The survey reports the time that people spend on various activities.

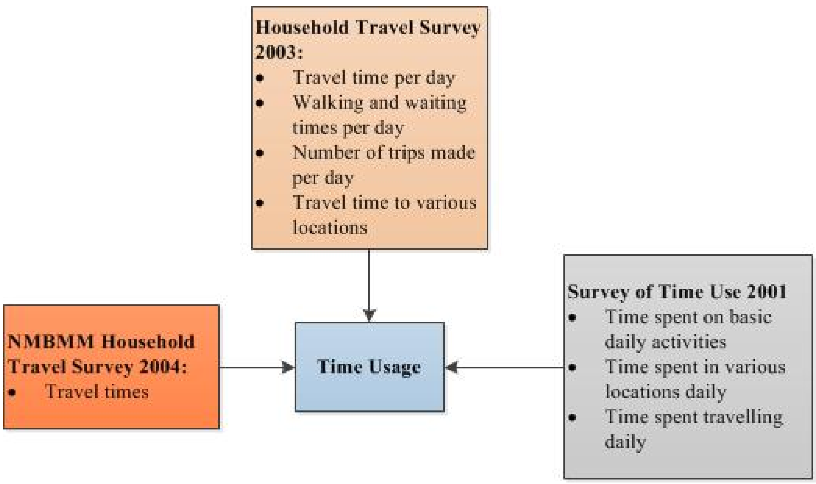


Figure 3.6: Data available for time usage.

3.2 Data to be Used for Metrics

This section focuses on the specific data sourced from various surveys in the development of the metric.

3.2.1 Synthetic Population Data

The synthetic population consists of two parts; socio-demographics and travel demand. The socio-demographics of the synthetic population was generated using the Census of 2001. The travel demand and behaviour was sourced from the Nelson Mandela Bay Metropolitan Travel Survey of 2004. The synthetic population is used to generate accessibility and affordability results for Nelson Mandela Bay Metropolitan. These results are used to test the metric's feasibility and show where the metric needs to be improved.

Population Socio-Demographics

Using data from the Census of 2001, a synthetic population, representing the current population in Nelson Mandela Bay Metropolitan, was built in another project. The household characteristics that were sourced and are relevant in the development of the metric, are mentioned below:

1. Socio-demographics data is provided on household size, population group, age, gender, household relationship, employment status and level of schooling.

2. Household income data on the amount of income of the household is available.

Travel Demand and Behaviour

Data from the Nelson Mandela Bay Metropolitan Travel Survey of 2004 was used in the synthetic population to determine the travel demand and behaviour of the population.

The data that has been sourced from the survey and is relevant in the development of the metric, is mentioned below:

1. Transport costs data is provided on the average cost per kilometer of public transport modes.

2. Public transport data is available on the modes of transport that are used.

3. Time usage data is available on the activity chains of an agent which convey data about the destinations that people travel to and the travel times and distances.

3.2.2 Transport Costs

The Automobile Association (2012) is used to source the average running costs per kilometer of a car.

3.2.3 Layout of Area

OpenStreetMap has been used for layout of the transport system of Nelson Mandela Bay Metropolitan. The layout of the area and the location of various facilities can be directly transferred to the simulation, allowing the tracking of people's movements between home, work, schools and shopping centres (OpenStreetMap, 2012).

Chapter 4

Metric Development

The metric is based the framework developed by Fan and Huang (2011). This framework looks at the needs of a household, therefore only taking needs-oriented travel into consideration. The following destinations are used for calculations of accessibility and affordability:

- Work.
- Education centers.
- Healthcare.
- Shopping centres.

For the purpose of this project, any activities taking place at these destinations are classified as basic activities, as done by Fan and Huang (2011).

Figure 4.1 shows the flow of the metric development, making it clear how the various data is incorporated into the design. The metric development consists of two parts; the model for accessibility is discussed in Chapter 5 and affordability is discussed in Chapter 6. The numbers in the blocks refer to the corresponding paragraphs in Section 5.1 and Section 6.1.

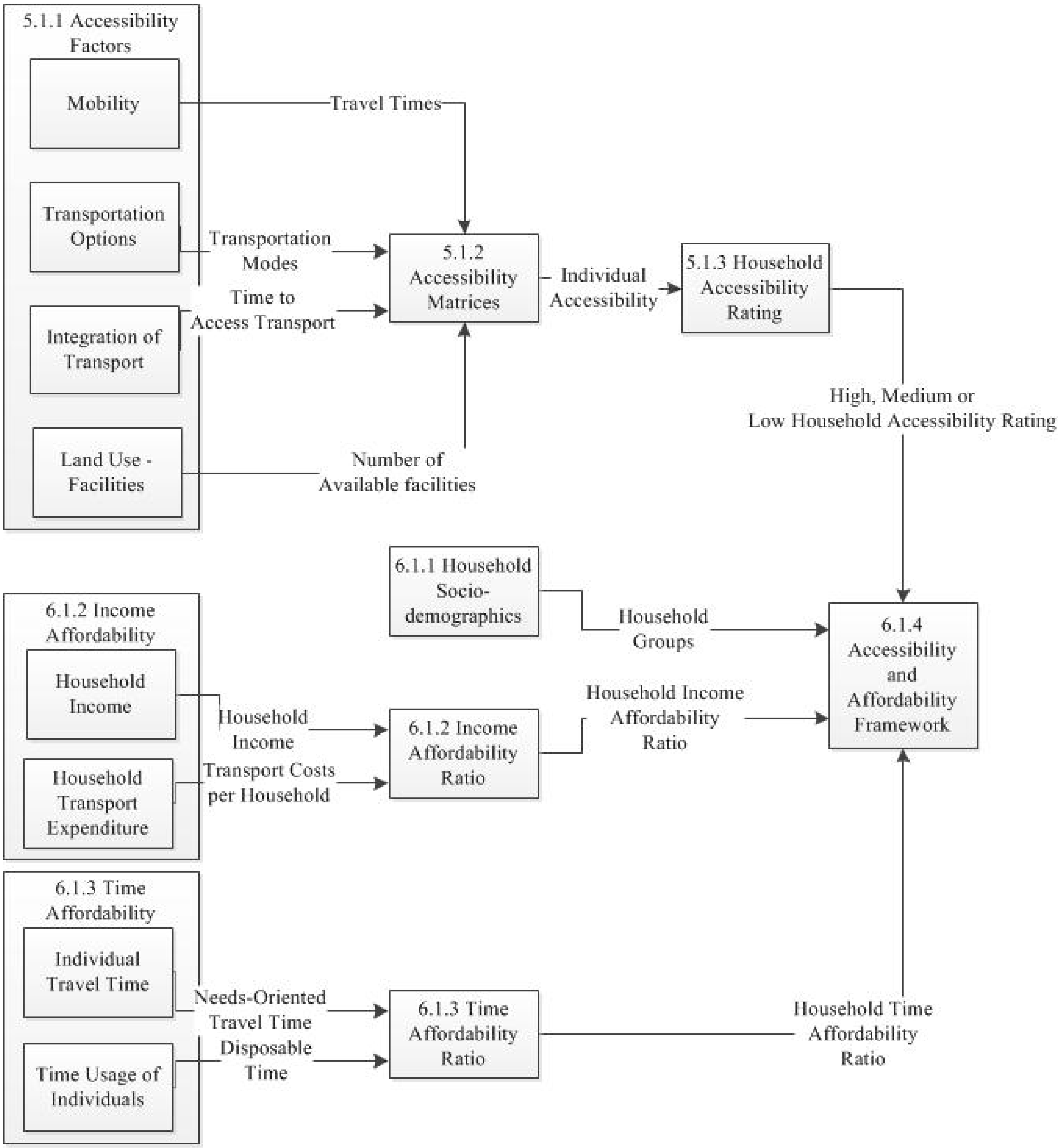


Figure 4.1: Flow diagram of the metric development.

Chapter 5

Accessibility of Transport Methodology and Results

5.1 Accessibility Methodology

5.1.1 Accessibility Matrices Factors

Four factors have been chosen to calculate the accessibility of a household.

Mobility This factor measures the travel time from the household location to education facilities, healthcare facilities, shopping centres and work. The trip is measured from the home location to keep the measurement consistent. Travel time includes the time that it takes to reach the chosen mode of transport and the travel time to the desired destination. Therefore, the entire link between home and destination is included. These travel times are sourced from the Nelson Mandela Bay Metropolitan Travel Survey of 2004.

By working with the estimated travel time, it creates the opportunity to eventually work with actual travel times. Actual travel times would include delays due to traffic. For example, a person might live within twenty minutes' walk from their destination, however if they drive there and the actual travel time is an hour due to traffic, the destination is not accessible.

The scoring of mobility can be seen in Table 5.1. The duration of travel time is given a score for each of the four possible destinations.

Table 5.1: Score for travel time.

Destination	**Score**		
	2	**1**	**0**
	Travel time (min)		
Education	≤ 30	31-60	> 60
Healthcare	≤ 30	31-60	> 60
Shopping Centre	≤ 15	16-30	> 30
Work	≤ 30	31-90	> 90

A score of 2 corresponds to a high accessibility, 1 to a medium accessibility and 0 to a low accessibility.

Transportation Options This factor quantifies the number of transport modes that are available to a household. Any mode of transport that is within 20 minutes' walking distance from the household, is considered an option of transport. This factor refers to options that are available from a geographic perspective, and not a person's willingness to use a mode of transport. The value of 20 minutes is taken from the Household Travel Survey 2003, where within 20 minutes, the majority of people are able to reach a station. These people are classified as short distance walkers, whilst long distance walkers are classified as people who walk for more than 20 minutes (Venter, 2011).

Walking speed is taken as 0.8333 m/s, which means on average, a person will walk 1km per 20 minutes (Average Walking, 2011).

The transport modes include bus, car, taxi, train and walking (long or short distance).

Table 5.2 refers to the points that a person gets if that mode of transport is available for use. The more options a person has, the more accessible the location of their house is.

Table 5.2: Points for available transportation options.

Transport Mode	**Points**
Car	5
Short distance walking	4
Taxi	3
Bus	2
Train	1
Long distance walking	0

The number of points that a person receives is summed. The total number of points is used to give a transportation options score, as seen in Table 5.3.

Table 5.3: Score for transportation options.

Score		
2	**1**	**0**
Points		
10-15	3-9	0-2

A score of 2 corresponds to a high accessibility, 1 to a medium accessibility and 0 to a low accessibility.

Integration of Transport This factor measures the walking time to reach the observed mode of transport.

The scoring for this factor can be seen in Table 5.4.

Table 5.4: Score for integration of transport.

Score		
2	**1**	**0**
Walking time (min)		
≤ 15	15-30	> 30

A score of 2 corresponds to a high accessibility, 1 to a medium accessibility and 0 to a low accessibility.

Land Use-Facilities This factor refers to the availability of facilities near a person's house. It looks at how accessible the home destination is to other facilities that a person requires access to. The more facilities situated nearby, the more accessible the location of their house is. If there is a facility within 20 minutes' walk, then it is considered accessible. These facilities include:

- Shop (food).
- Shop (other).
- Healthcare.
- Police station.
- Post office.
- Education.
- Petrol station.
- Bank including ATM.

These facilities can be seen on the OpenStreetMap layout of Nelson Mandela Bay Metropolitan, and therefore the number can be counted for each household.

Work places are not considered. This is due to the fact that there may be a work area very near to a household, but if a person is not qualified to work there, they cannot work at that place. Therefore a person should not receive points for work places that they cannot work at.

The number of accessible facilities and the scoring thereof, can be seen in Table 5.5.

Table 5.5: Score for land-use facilities that are accessible with 20 minutes' walk.

Score		
2	**1**	**0**
Number of Facilities		
> 10	$6 - 10$	$0 - 5$

A score of 2 corresponds to a high accessibility, 1 to a medium accessibility and 0 to a low accessibility.

The original matrix would have included waiting time for transport and the number of trips that need to be taken in order to reach the desired destination. For example, a person going to work might first have to walk to the taxi, then take a taxi and once again walk to reach the work place, taking three trips. However, the synthetic population currently does not have enough data available for these factors. It is suggested that these factors be added to the accessibility matrices once the model has matured and is capable of providing output on this data.

5.1.2 Accessibility Matrices

Each person living in a household has different attributes. For example, an adult goes to work and a child goes to school. A single measurement for the entire household does not reflect the individuals' needs. Therefore, each individual's accessibility is measured and then the household's score is calculated as an average of the accessibility scores.

The following steps are followed when setting up the matrix:

1. The matrix is drawn up using each of the four above mentioned factors. Each factor has at least one measurement. For example, travel time is a measurement of mobility.

2. Each factor is given a weight of 10.

3. Each measurement under each factor is given a weight, so that the total is 10 for all the measurements in the factor group. For example, if there are four measurements in the group, each measurement has a weight of 2.5, making up a weight of 10.

4. The final score of the individual is calculated.

5. The final average score of the household is calculated.

The individual accessibility rating is calculated using a different matrix for each type of person living in the household, namely:

- Employed adult taking children to school, as seen in Table 5.7.

- Employed adult, does not take children to school, as seen in Table 5.8.

- Unemployed adult taking children to school or scholar, as seen in Table 5.9.

- Children going to school, as seen in Table 5.9.

- Unemployed adult, does not take children to school, as seen in Table 5.10.

The reported activities in the activity chains are used to identify each type of person. Table 5.6 shows the different activities.

Table 5.6: Activity symbols used in activity chains

Symbol	**Activity**
e_1	School-going
e_2	Tertiary education
e_3	Dropping children at school
h	Home
l	Leisure
o	Other
s	Shopping
w	Work

A person with the symbols "e_3 and "w" in their activity chain is a parent dropping their children off at school and then going to work. Therefore, this person falls into the "employed adult taking children to school" category. A child will have an "e_1" symbol in their activity chain, whilst an unemployed adult not taking children to school has neither "w" nor "e_3" in their activity chain.

Model of Matrices

The matrices are developed using the previously mentioned accessibility factors.

Table 5.7 is the accessibility matrix for an employed adult who has to take children to school. An example of this type of person may be a working mother who takes the children to school. A person using this matrix has to have access to education, healthcare, shopping and work facilities.

Table 5.7: Accessibility matrix for employed adult taking children to school.

		Score		
Accessibility Factors	**Weight**	**2**	**1**	**0**
Mobility				
Travel time to education (min)	2.5	≤ 30	31-60	> 60
Travel time to healthcare (min)	2.5	≤ 30	31-60	> 60
Travel time to shopping Centre	2.5	≤ 15	16-30	> 30
Travel time to work	2.5	≤ 30	31-90	> 90
Transportation Options				
Points for available transport within 20 minutes	10	10-15	3-9	0-2
Integration Facilities				
Walking time to reach chosen transport service (min)	10	≤ 15	15-30	> 30
Land Use				
Facilities available within 20 minutes' walk	10	> 10	6-10	0-5
Total Score				

Table 5.8 is the accessibility matrix for an employed adult who does not have to take children to school. An example of this type of person may be a working father who leaves home and travels directly to work. A person using this matrix has to have access to healthcare, shopping and work facilities.

Table 5.8: Accessibility matrix for employed adult not taking children to school.

		Score		
Accessibility Factors	**Weight**	**2**	**1**	**0**
Mobility				
Travel time to healthcare (min)	3.33	≤ 30	31-60	> 60
Travel time to shopping Centre	3.33	≤ 15	16-30	> 30
Travel time to work	3.33	≤ 30	31-90	> 90
Transportation Options				
Points for available transport within 20 minutes	10	10-15	3-9	0-2
Integration Facilities				
Walking time to reach chosen transport service (min)	10	≤ 15	15-30	> 30
Land Use				
Facilities available within 20 minutes' walk	10	> 10	6-10	0-5
Total Score				

Table 5.9 is the accessibility matrix for an unemployed adult who has to take children to school. An example of this type of person may be a stay at home mother who takes and fetches the children from school. A person using this matrix has to have access to education, healthcare and shopping facilities.

Table 5.9: Accessibility matrix for unemployed adult taking children to school.

		Score		
Accessibility Factors	**Weight**	**2**	**1**	**0**
Mobility				
Travel time to education (min)	3.33	≤ 30	31-60	> 60
Travel time to healthcare (min)	3.33	≤ 30	31-60	> 60
Travel time to shopping Centre	3.33	≤ 15	16-30	> 30
Transportation Options				
Points for available transport within 20 minutes	10	10-15	3-9	0-2
Integration Facilities				
Walking time to reach chosen transport service (min)	10	≤ 15	15-30	> 30
Land Use				
Facilities available within 20 minutes' walk	10	> 10	6-10	0-5
Total Score				

Table 5.9 is also the accessibility matrix for a child going to school. An example of this type of person is a child who has to organise their own transport to get to school, and then on the way home buy bread from the shops. A person using this matrix has to have access to education, healthcare and shopping facilities.

Table 5.10 is the accessibility matrix for an unemployed adult who does not have to take children to school. An example of this type of person may be a housewife who has children that can walk to school. A person using this matrix has to have access to healthcare and shopping facilities.

Table 5.10: Accessibility matrix for unemployed adult not taking children to school.

		Score		
Accessibility Factors	**Weight**	**2**	**1**	**0**
Mobility				
Travel time to healthcare (min)	5.0	≤ 30	31-60	> 60
Travel time to shopping Centre	5.0	≤ 15	16-30	> 30
Transportation Options				
Points for available transport within 20 minutes	10	10-15	3-9	0-2
Integration Facilities				
Walking time to reach chosen transport service (min)	10	≤ 15	15-30	> 30
Land Use				
Facilities available within 20 minutes' walk	10	> 10	6-10	0-5
Total Score				

5.1.3 Household Accessibility Rating

Once each individual in the household is given an accessibility score, the score for the household can be calculated using the average of the individuals. A 25% random sample of the synthetic population of Nelson Mandela Bay Metropolitan is used to calculate the accessibility. The sample is random and large enough to be statistically representative of the entire population, and should produce similar results to if the 100% sample was used. The 25% sample is used for convenience of calculating and testing the feasibility of the metric. Running the 100% sample would be very time consuming, which would unnecessarily lengthen the metric development process.

The distribution of the household accessibility scores is demonstrated in Figure 5.1. The accessibility rating is calculated using the distribution of accessibility scores. A household with an accessibility score equal to or lower than 44.67, the $33\frac{1}{3}^{\text{rd}}$ percentile, is classified as a low accessibility household. An accessibility score between 44.67 and 54.71, the $66\frac{2}{3}^{\text{rd}}$ percentile, is classified as a medium accessibility household. An accessibility score above 54.71 is classified as a high accessibility household.

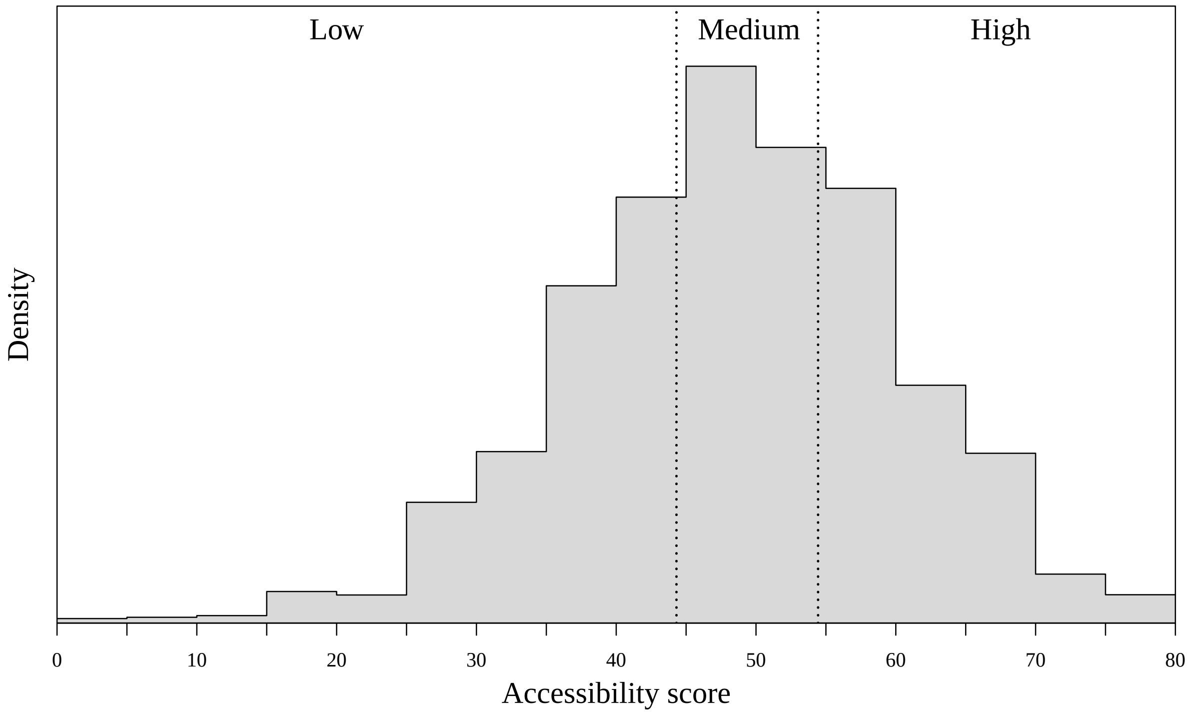


Figure 5.1: Histogram of accessibility scores.

5.2 Accessibility Score Results

The results of the accessibility scores are discussed by looking at the spatial representation of the results, followed by a discussion of the statistical results.

Figure 5.2 is a map of Nelson Mandela Bay Metropolitan. This map is included so that the spatial representations of results in the following sections can be understood in terms of where various areas are situated.

Figure 5.2: Map of Nelson Mandela Bay Metropolitan (AfriGIS (Pty) Ltd, Google, 2012).

5.2.1 Spatial Representation of Accessibility

Figure 5.3 is a visual representation of the accessibility scores. In this map, it is clear that there are different areas with distinctly different accessibility scores. Red indicates that a household has a very low accessibility, whilst dark blue indicates that a household's accessibility is very high.

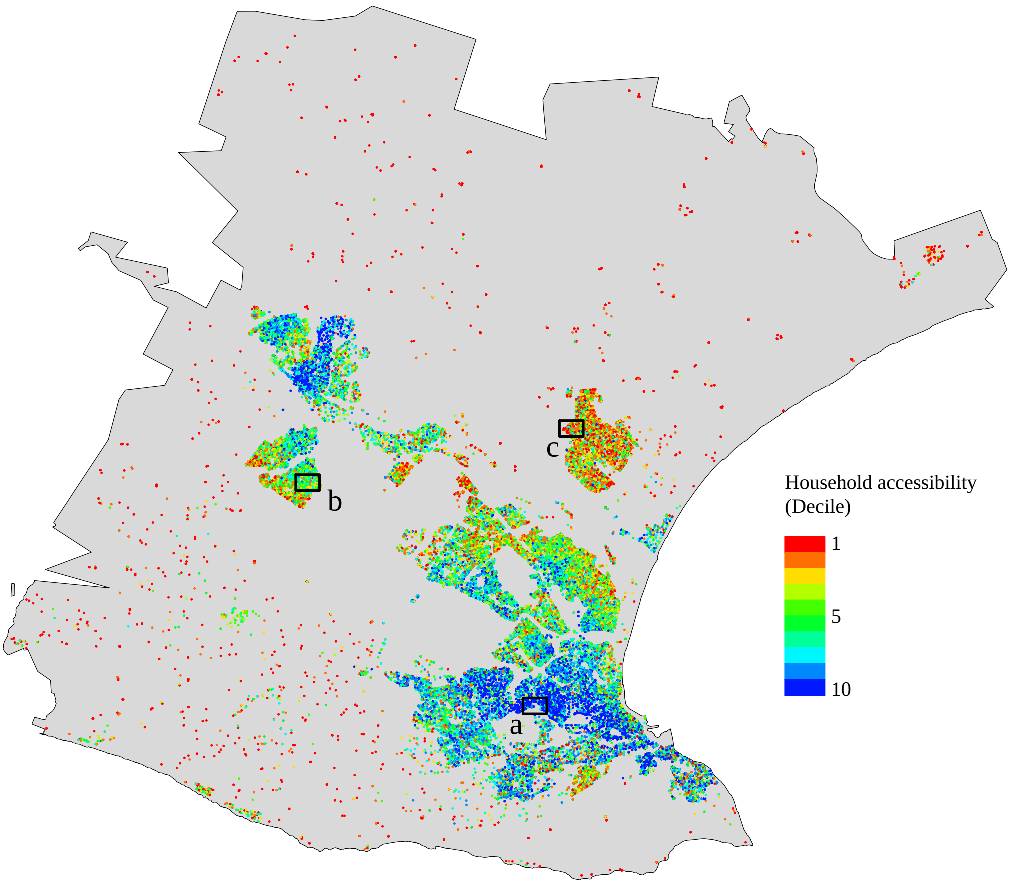


Figure 5.3: Spatial distribution of the accessibility scores.

In Figure 5.3, it can be seen that certain areas tend to be clustered in terms of their accessibility rating. The Port Elizabeth area, situated in the bottom right of the map, is dark blue. This is due to the area being very accessible in terms of transport, schools and other facilities. Therefore, it is easy for people to access a variety of facilities.

There are many red dots in the surrounding areas. These dots are of households that live relatively far from the urban areas, making it more difficult to access facilities. A person's travel time and distance to reach a desired destination is much longer than for a person living in a suburban area. The amount of transport available in poorly accessible areas is also less than in the city.

Three areas, *a*, *b* and *c*, are highlighted. These areas refer to the aerial photographs in Figure 5.4, which demonstrate the different accessibility ratings of areas. Each of these photographs are taken at the same scale. Area *a* has a high accessibility, area *b* has a medium accessibility and area *c* has a low accessibility.

(a) High accessibility

(b) Medium accessibility

(c) Low accessibility

Figure 5.4: Aerial photographs of areas with notably different accessibility (Source: South African National Geospatial Institute (NGI) imagery available on *OpenStreetMap*.

In Figure 5.4a, one can see that there are various types of facilities in the area. This area is the city of Port Elizabeth, which has a very high accessibility. The photograph shows a suburban area. The houses are big and many have swimming pools, indicating that households can afford to maintain luxury recreational facilities. On the top right hand side of the photograph, there are many larger buildings. These include shopping centres, restaurants, a primary school, a post office, a clinic, a petrol station, a bank, a library, a church and sport facilities. Households have very high mobility because their travel time is minimal when travelling to desired destinations. There are primary roads in the area, which increases accessibility to public transport and the ease with which other areas can be accessed. Therefore, for a person living in this area, there is a large variety of facilities very nearby and easily accessible.

In Figure 5.4b, it is clear that the area is not as accessible as Figure 5.4a. This is Kwa Nobuhle, a township situated near Uitenhage. There are many houses in the area and not as many other facilities. The houses are smaller, however the density of people living in the area is larger than in Figure 5.4a. It is usually the case that informal areas are much more densely populated than urban areas. The large buildings that can be seen on the photograph are primary and secondary schools. The mobility of a household is decreased because a household's travel time is longer when going to work, clinics or shopping centres. It is likely that there is sufficient public transport available in the area because it is situated very near to Uitenhage, which is where many facilities are located. Therefore, the area's accessibility is medium because there are some facilities available, but they are further away and not very accessible.

Motherwell, a township in Nelson Mandela Bay Metropolitan, is shown in Figure 5.4c. This area has a low accessibility because there are very few facilities available in the area. In the bottom right hand corner there is an intermediary school, otherwise the rest of the area that can be seen is just housing. The area is very densely populated, and the houses are much smaller than in Figure 5.4a. This indicates that the people living in the area are from low-income households and the housing is informal. This clearly demonstrates that low accessibility is often associated with low-income households. Motherwell is relatively far from any shopping centre, clinic or any other facility that a household would require access to. Therefore, a household's mobility is decreased because they have to travel for longer periods of time to reach their desired destination. It is likely that transport is not readily available because the area is not very near to primary roads. Consequently, people that require public transport need to walk further to access it, thereby decreasing their accessibility.

5.2.2 Accessibility Statistics

In Section 5.1.3, the different ratings of accessibility were categorised for low, medium and high scores. In Table 5.11, the distribution of accessibility scores in terms of percentiles can be seen.

Table 5.11: Household accessibility score percentiles.

Accessibility Score Percentile					
25%	**50%**	**75%**	**90%**	**95%**	**99%**
43.67	51.11	58.33	65.00	68.89	76.25

75% of households' accessibility score is 58.33 or less. This means that most households have a low or medium accessibility and a much smaller percentage of the population have a high accessibility. The Community Survey of 2007 found that approximately 62% of people living in Nelson Mandela Bay Metropolitan earned less than R1600 per month. This falls into a low-income category, giving credit to the theory that high accessibility is attributed to high-income households who can afford to live in suburban areas.

Areas that are further from the city and facilities, tend to be low-cost housing, such as in Figure 5.4b and Figure 5.4c. The houses in these areas are much smaller than in 5.4a, and therefore housing costs substantially less than in suburban areas. The houses in these areas are likely to be built by the government or are informal dwellings. People living in these areas have to travel further to their desired destinations than those living in suburban areas, making these areas less accessible. Therefore, people living in less accessible areas have higher transport costs, but cheaper housing costs. It is therefore evident that South Africans face trade-offs between housing and transport costs, as described by Lipman (2006).

The accessibility matrices provide feasible results for the accessibility of transport in South Africa. Evidence of the theory that rural areas experience poor transport accessibility, whilst suburban areas experience high transport accessibility, is given. In order to improve the accessibility of these areas, transport needs to be made more readily available. The government could implement an integrated transport system, consisting of taxis, buses and trains, in order to improve the accessibility of households. Alternatively, they could build schools, factories and shopping centres in poorly accessible areas.

Chapter 6

Affordability of Transport Methodology and Results

6.1 Affordability Methodology

Transportation affordability is dependent on a household's needs, as well as the cost of their chosen mode of transport. The needs of a household are determined by their socio-demographics, as well as the location of their house and their destination. The household socio-demographic groups determine the amount of time and income that a household has available to spend on transportation. The socio-demographic groups that are used in the measurement of affordability must reflect the type of households that are found in South Africa.

Figure 4.1 describes the factors that are used in the development of an affordability measurement and assists in understanding what transportation affordability is made up of.

In this section, time and income affordability ratios are used to assess a household's time and monetary expenditure on transport.

6.1.1 Household Socio-demographics

The household sizes in South Africa are very diverse. It is common in low-income households for extended families to live together, and the metric needs to accommodate for this fact. Fan and Huang (2011) identified 12 different socio-demographic groups. There are four factors that are considered in these groups, namely:

- Employment status.
- Number of workers in household.
- Marital status.
- Children in household.

Due to the diversity of South African households, the socio-demographic groups that are used are more generalised. The types of households are grouped according to the people living there, therefore the number of adults and children living in the household. Affordability is assigned according to the household type and their accessibility rating.

This grouping allows for various types of households, from a single adult to a household where grandparents, parents and children live together.

The socio-demographic groups that are used in the accessibility and affordability framework include:

- Single adult with no children.
- Single adult with children.
- Multiple adults with no children.
- Multiple adults with children.

The classification of socio-demographic household groups allows for the affordability of the household to be calculated using two ratios: income affordability and time affordability. These ratios are calculated for each household type with the associated accessibility rating.

6.1.2 Income Affordability

The income affordability ratio, Equation (6.1), calculates the percentage of income that the household spends on needs-oriented transport, or the proportion of income spent accessing needs-oriented destinations. This gives an indication of the proportion of income resources that go towards transportation.

$$\text{Income Affordability Ratio} = \frac{\text{Needs-oriented transportation expenditure}}{\text{Household income}} \times 100 \quad (6.1)$$

The monthly household income is used in the income affordability ratio. Household transport expenditure consists of private and public transport costs. Private transport costs include the amount spent on fuel, car maintenance and toll charges. Public transport costs include bus, train or taxi fares. The expenditure on transport can be simplified to the cost per kilometer of travel. From the Nelson Mandela Bay Metropolitan Travel Survey of 2004, data was collected on the average cost per kilometer for public transport, which can be seen in Table 6.1.

Table 6.1: Average public transport costs (Nelson Mandela Bay Municipality, 2006).

Transport Mode	**Cost per kilometer (R)**
Taxi	0.34
Bus	0.19
Train	0.17

The Automobile Association (2012) estimates the running costs per kilometer of various types of cars. An average 1.6 litre car, which is a low range car, has a running cost of R2.53 per kilometer. This is used as an estimate of private transport expenditure.

A household's income can be made up of contributions by more than one person in the household. For example, a household with more than one adult may have one breadwinner, and the other adults in the household choose not to work. Another example would be a household with two working adults, as well as elderly people who no longer work. The income for this household would then consist of the salaries earned by the adults and the pensions of the elderly people. Therefore, employment and unemployment are considered in the income affordability ratio.

The less income a household has available, the larger the expected percentage expenditure of transport. For example, a household where the adults are unemployed most likely relies on grants as a type of income. Therefore, a minimum amount of income is available to spend, and the household spends a large proportion of their income when using public or private transport.

6.1.3 Time Affordability

The time affordability ratio, Equation (6.2), calculates the percentage of household time that is spent on needs-oriented travel.

$$\text{Time Affordability Ratio} = \frac{\text{Needs-oriented travel time}}{\text{Household disposable time}} \times 100 \tag{6.2}$$

The needs-oriented travel time looks at the amount of time a person spends travelling to a needs-oriented destination, therefore the cost of transport in terms of time. Disposable time is defined in this project as defined in the work done by Fan and Huang (2011). Disposable time is measured by subtracting the amount of time spent on basic activities from 24 hours, and then averaged for the household. Basic activities include being at work, education, healthcare and essential shopping activities. Essential shopping activities are assumed to be when a person shops for necessary items, such as food. In the Nelson Mandela Bay Metropolitan Travel Survey of 2004, people reported activities at shopping centres as either a shopping activity ("s") or a leisure activity ("l"). These symbols can be seen in Table 5.6. Therefore, any shopping activity ("s") is assumed to be essential shopping. Leisure activities ("l") do not form part of basic activities as these activities are not part of a household's basic needs.

6.1.4 Accessibility and Affordability Framework

Figure 6.1, which is part of Figure 4.1, demonstrates the final step in the metric development. The accessibility rating and the affordability ratios are brought together to form the final accessibility and affordability framework, which can be seen in Table 6.2.

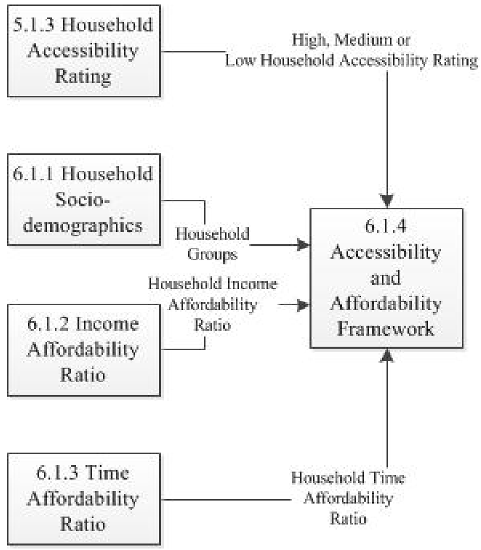


Figure 6.1: Accessibility and affordability framework development.

Using this framework, a household is categorised according to a socio-demographic group and their accessibility rating. The income and time affordability ratios are then calculated to determine their affordability.

Table 6.2: Accessibility and affordability framework.

	Accessibility		
Household Groups	**High**	**Medium**	**Low**
Single adult, no children	T_{income}, T_{time}	T_{income}, T_{time}	T_{income}, T_{time}
Single adult, with children	T_{income}, T_{time}	T_{income}, T_{time}	T_{income}, T_{time}
Multiple adults, no children	T_{income}, T_{time}	T_{income}, T_{time}	T_{income}, T_{time}
Multiple adults, with children	T_{income}, T_{time}	T_{income}, T_{time}	T_{income}, T_{time}

T_{income} and T_{time} refer to the ratios that are used, namely Equation (6.1) and Equation (6.2).

6.1.5 Affordability of Household

To calculate the affordability for each type of household, the following steps are taken:

1. Calculate the income and time affordability ratios for each type of household.
2. Calculate the statistics of the income and time affordability ratio results.
3. Graph the affordability ratio results with the associated accessibility rating as a histogram for each household group. These histograms are the results of the accessibility and affordability framework, which are summarised in a table.
4. Analyse the results to determine what is considered affordable.

Once all the ratios have been calculated for Nelson Mandela Bay Metropolitan, a household's affordability can be determined to see where they fall in terms of affordability.

6.2 Affordability Results

The results of affordability are discussed separately in terms of income affordability and time affordability.

Any household that did not have an income was omitted from these results because they skewed the data incorrectly. Figure 6.2 shows the locations of all these households. A black dot is an indication of a zero-income household. The income affordability ratio could not be calculated for these households because they either had an income affordability ratio of zero, or the ratio was undefined. Their transport expenditure should be zero, which is theoretically the ideal ratio. However, these households do not spend money on transport for the reason that they cannot afford it, not because they choose not to use transport.

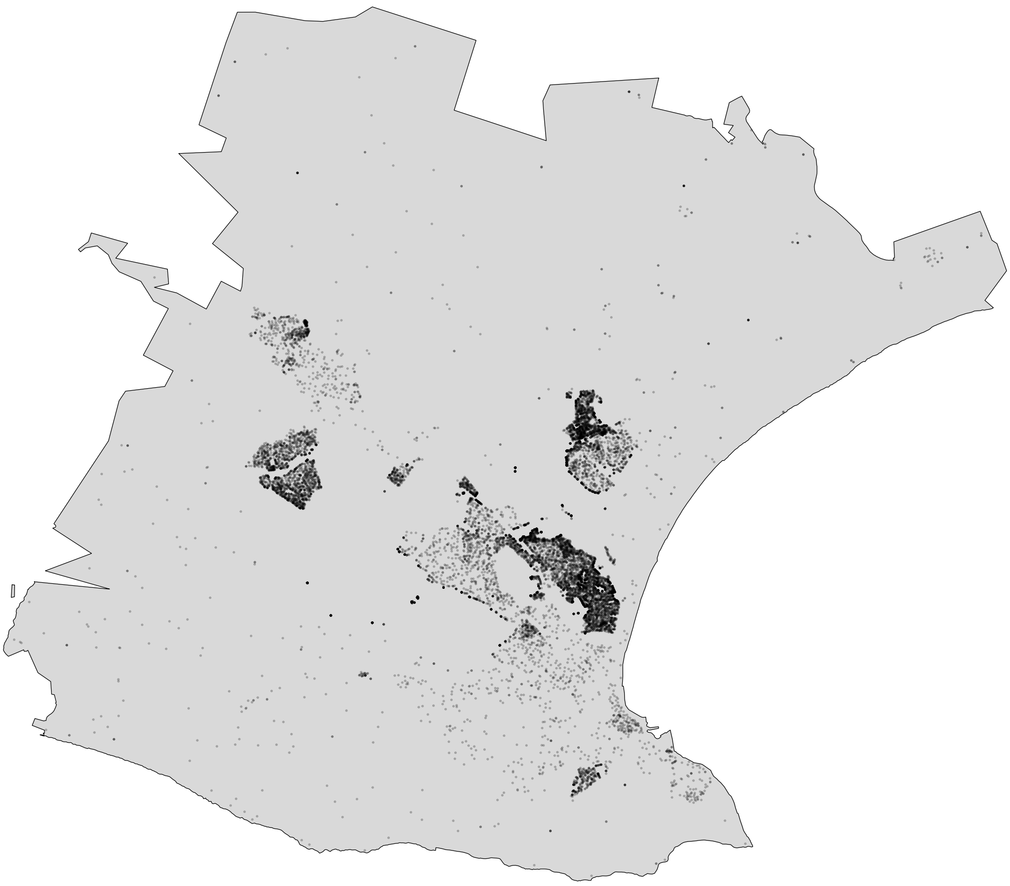


Figure 6.2: Map of zero-income households.

The majority of households with no income live in the township areas, which are indicated by the very clustered areas on the map. These are iBhayi, the large cluster on the middle right of the map, Kwa Nobuhle, the large cluster on the left of the map, and Motherwell, the large cluster towards the top of the map. The exact locations of these townships can be seen in Figure 5.2.

6.2.1 Income Affordability Results

Spatial Representation of Income Affordability

The results of the income affordability ratios are represented spatially in Figure 6.3. Blue indicates a high income affordability ratio, indicating that transport is very affordable. Red indicates that transport is very unaffordable for this household.

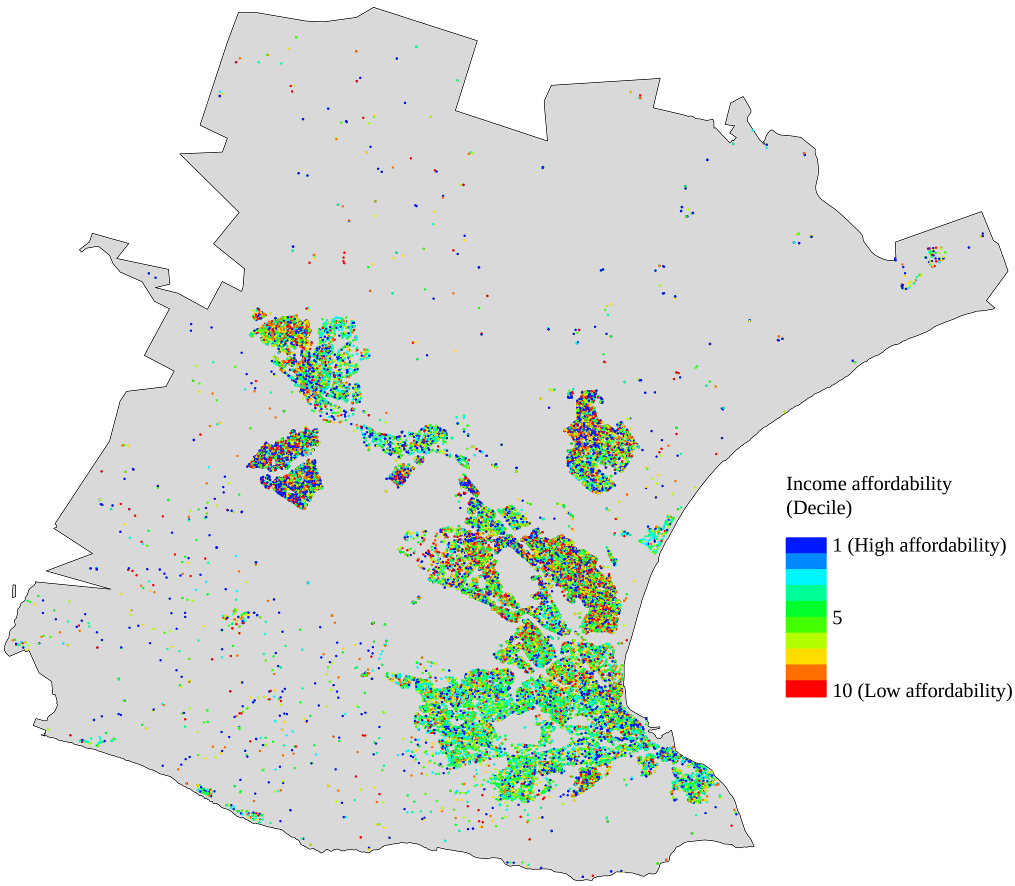


Figure 6.3: Spatial distribution of the income affordability scores.

Distinct patterns of income affordability cannot be seen, as was seen in the spatial representation of the accessibility scores in Figure 5.3.

Townships, such as Kwa Nobuhle and Motherwell, have a range of different income affordability ratios, whilst urban areas, such as Uitenhage and Port Elizabeth, have a range between medium and high income affordability. The locations of these areas can be seen in Figure 5.2. People living on the outskirts of the metropolitan also have a range of different income affordability ratios.

Possible reasons for the scattered distribution include:

- People living in townships often walk to their destinations.
- People living in suburban areas have access to private transport, which pushes up their transport expenditure.

- People living in destinations that are not accessible, make fewer trips than people living in accessible destinations. For example, they do groceries monthly, not daily or biweekly. Or they choose to live in areas with low accessibility and drive to their destinations that are further away, because they can afford to do so.

Income Affordability Statistics

Table 6.3 provides the overall summary statistics of the income affordability of the sample population. The ideal income affordability ratio would be as close to 0% as possible. This would indicate that the household lives in a very accessible area and can walk or cycle to all their destinations.

The 100^{th} percentile is not included in order to omit the extreme outliers. The 99^{th} percentile represents the maximum range. Single adults with no children spend the smallest percentage of their income on transport, whilst multiple adults with children spend the largest percentage of their income on transport. When there are children in the household, the income affordability ratio is a lot higher than when there are no children.

Table 6.3: Income affordability ratio for different household classes as a percentile.

		Income Affordability Ratio Percentiles					
Household class	**Mean**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
Single adult, no children	3.48%	0.00%	0.00%	3.78%	9.23%	13.13%	30.04%
Single adult, with children	8.08%	0.00%	1.79%	7.10%	16.71%	36.00%	93.46%
Multiple adults, no children	6.06%	0.32%	2.57%	6.38%	13.42%	21.32%	77.03%
Multiple adults, with children	11.30%	1.55%	4.40%	10.27%	23.58%	44.19%	115.20%

The 99^{th} percentile values seem to be much larger than the 95^{th} percentile values. The possible reasons for this difference are:

- These values are outliers of households who spend excessive amounts of income on transport. They may live very far from their destinations, which would therefore push up their transport costs. The other possibility is that high-income households have more income available to spend on transport and therefore choose to travel to many more destinations because they can afford it.

- OpenStreetMap is being used to route the road network. This is a crowd-sourced program, which means that any person has access to the data, as well as access to make any changes to the data. It is possible that the map is not completely accurate. A household may be routed incorrectly and thereby add extra transport costs.

The various statistics are discussed in more detail below, with reference to the corresponding income affordability histograms for the different household groups.

Income Affordability Histogram Statistics

One income affordability histogram from each household group is discussed in detail. The histograms for each household group with the associated accessibility class, Figures B.1–B.4, can be seen in Appendix B.1. Table 6.4 is a summary of the data that is represented by the histograms.

Table 6.4: Mean and median of income affordability ratios of household classes with associated accessibility rating.

Household class	**Accessibility**					
	Low		**Medium**		**High**	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Single adult, no children	3.34%	0.00%	2.94%	0.00%	3.73%	0.92%
Single adult, with children	8.16%	1.10%	8.87%	2.24%	6.70%	1.85%
Multiple adults, no children	6.41%	1.51%	7.26%	2.51%	6.33%	2.87%
Multiple adults, with children	13.01%	4.76%	12.32%	4.87%	8.44%	3.73%

The mean of each group is greater than the median, therefore all histograms are skewed to the right. Only a small percentage of households spend more than the mean. Reasons for this could be:

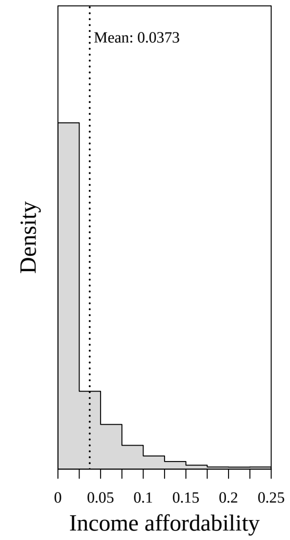
- People live far from work and have to spend more of their income travelling on a daily basis.
- The mode of transport that is used is expensive. The cost per kilometer of a car is much higher than the cost per kilometer for public transport.

In Table 6.4, it can be seen that when the accessibility of the household increases from low to medium to high, the mean does not follow a pattern of either increasing or decreasing. It would be expected that as accessibility increases, the income affordability ratio would decrease, as people live closer to facilities. However, this is not always the case. Possible reasons include:

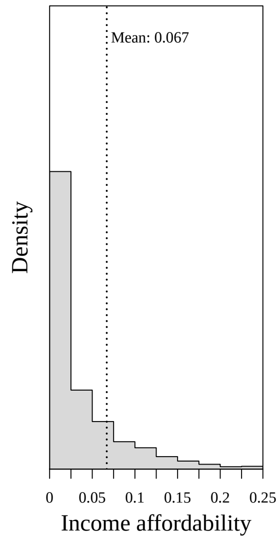
- Households with low accessibility are mostly made up of low-income households. In these households, it is likely that one or two adults are supporting the entire extended family. There is less income available to provide transport for a bigger household, increasing the income affordability ratio.
- With increased accessibility, households have higher incomes. People tend to spend what they have, therefore they travel, increasing their transport expenditure.
- Children in households with higher accessibility are able to walk to school. Therefore, the adult would not have to drop the children off and could drive straight to work. However, in high-income households, parents are likely to drop their children off at school because they can afford to do so, increasing their transport expenditure.

6.2.2 Income Affordability Histograms for Households with High Accessibility

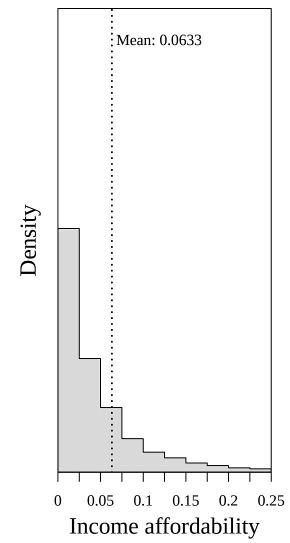
Figure 6.4 is the income affordability histograms of each household group for a high accessibility rating. These histograms were chosen to discuss as they demonstrate the distribution of the income affordability ratio well. The histograms for the remaining accessibility ratings can be seen in Appendix B.1.



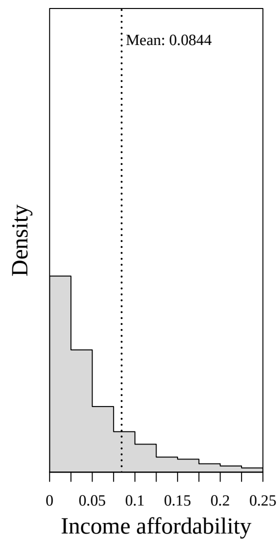
(a) Single adult, no children household



(b) Single adult, with children household



(c) Multiple adult, no children household



(d) Multiple adult, with children household

Figure 6.4: Income affordability ratio histograms of households with high accessibility.

A *single adult no children household* has the smallest mean income affordability ratio, followed by a *multiple adults with no children household.* A *single adult with no children household* only has one person living in this household, therefore the majority of their transport costs go towards travelling to work during the week. It is likely that these households stop at shopping centres or clinics as part of their trip to or from work, therefore minimizing the distance that they travel and their transport expenditure.

In a *multiple adult with no children household*, multiple adults are all able to contribute towards the household income and therefore it is likely that there is more income available to spend on transport. Although there may be a higher household income, it is used for the transport of multiple adults. The adults may all be contributing to the income, however one adult may have a full-time job and the other adult in the household only has a part-time job. If this is the case, the household income is 1.5 times the amount it would have been for a *single adult with no children household*, and therefore the proportion of household income that is spent on the transport of two adults is higher than the proportion of one adult.

A *single adult with children household* has a mean that is greater than a *single adult with no children household* and a *multiple adults with no children household.* This is plausible, since the household needs to accommodate for taking the children to various destinations, including education facilities. The adults in the household need to organise transport for themselves to get to work, shopping centres and clinics, but also ensure that the children have transport, which increases the household income affordability ratio.

A *multiple adults with children household* has the highest mean income affordability ratio of the household classes. It is likely that there are multiple incomes contributing to the household income, however the children do not contribute to this. Although there may be more income available than in a *single adult household with children*, there are more people in the household that have to travel. Children often have to be taken to their destinations, therefore an adult is likely to incur travelling costs that would have been avoided if there were no children in the household. Consequently, multiple adults and children in a household increase the income affordability ratio.

As can be seen in Figure 6.4, the majority of households have a ratio between 0% and 2.5%. This is good because it indicates that their transport is affordable. A *single adult with no children household* has the highest density of people in this interval. As the number of adults and children increases, the number of households in this interval decreases. Therefore, this further validates the above statement that multiple adults and children increase the income affordability ratio.

Income Affordability Findings

It was found in the National Income and Expenditure Survey of 2006 that the proportion of transport expenditure has increased since 2000. The reason for this was that incomes increased by 17.2% and people were able to purchase their own cars (Statistics South Africa, 2008b). This could explain the scattered income affordability ratios. Households may have bought a car but not moved to a more accessible area, for reasons such as not wanting their children to change schools. Therefore, their transport costs would have increased substantially, as well as the proportion of income spent on transport.

South Africa has experienced dramatic increases in fuel and electricity prices in the last few years. Increases in fuel prices lead to increases in transport costs. People using private transport would be more affected by these increases than people using public transport. This could have contributed to the scattered income affordability ratios as some households are affected more than others, depending on their choice of transport. Another reason for the scattered affordability ratios could be that households spend more than they earn. It is estimated that almost 90% of South Africans spend more than they earn in order to maintain a certain standard of living (STANLIB, 2012). Therefore, many South Africans buy things using credit. This poses a problem for measuring affordability, as it is difficult to measure what the household is actually capable of spending when they use credit.

HIV / Aids is a major problem in South Africa. In 2010, it was estimated that 5.24 million people were living with HIV (Statistics South Africa, 2010). This is a prevalence rate of approximately 10.5%. Many people have died of Aids complications, leaving orphaned children. These children then go and live with their grandparents, who are surviving on government grants or the children live by themselves and have to work. These households are further disadvantaged by having to support extra people, contributing to the scattered income affordability ratios.

In Figure 5.3, it can be seen that suburban areas have much higher accessibility than remote areas. The people that can afford to live in suburban areas usually have access to private transport. As accessibility increases, there is sometimes a slight increase in the percentage of transport expenditure, as seen in Table 6.4. It is likely that households with low accessibility are low-income households that live in remote areas, therefore they have less income available to spend. These households are likely to walk or use a taxi, which is much cheaper than driving. Therefore, as accessibility increases, the percentage of income spent on transport is likely to increase because these households spend more on private transport.

6.2.3 Time Affordability Results

Spatial Representation of Time Affordability

The results of the time affordability ratio are represented spatially in Figure 6.5. Blue indicates a high time affordability ratio, indicating that minimal time is spent travelling. Red indicates that the household spends a large portion of their disposable time travelling.

There are not very distinct patterns that can be seen in the spatial representation of time affordability, as seen with the accessibility scores in Figure 5.3.

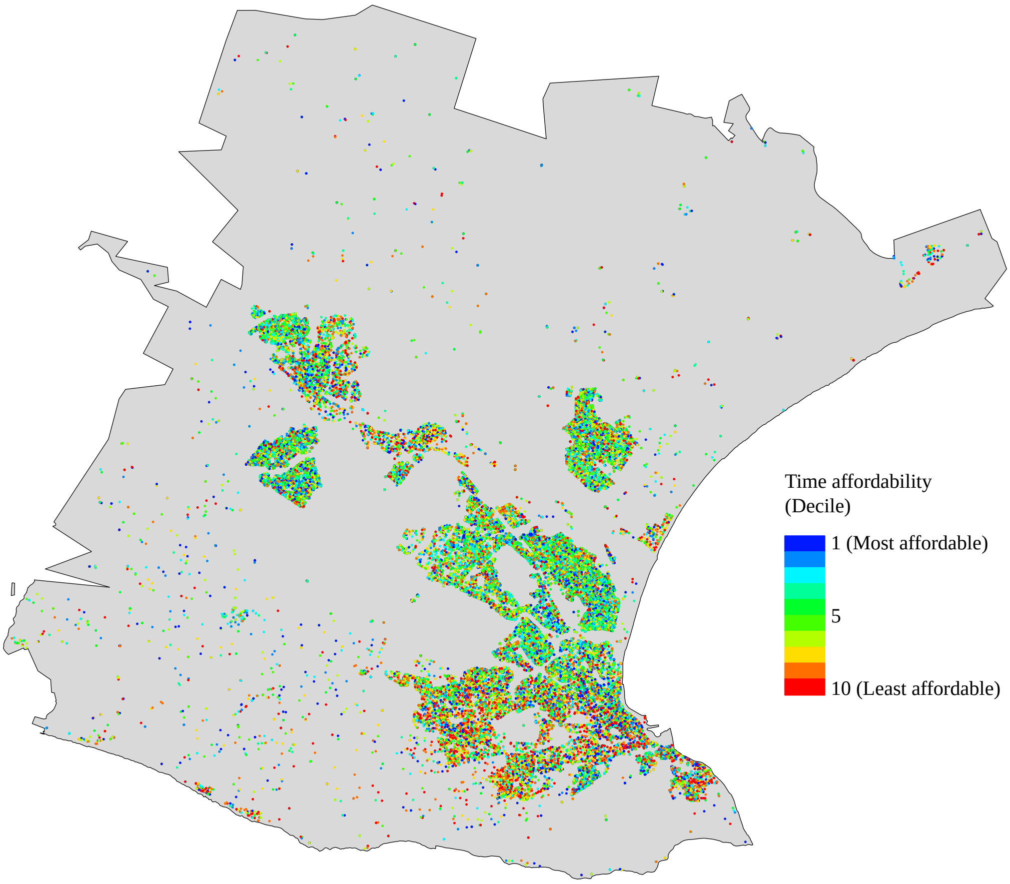


Figure 6.5: Spatial distribution of the time affordability scores.

In most areas, households predominantly have a medium time affordability. In the middle of the Port Elizabeth area, there is a slight increase in the affordability of time, whilst in Walmer, a township situated just below Port Elizabeth, there is a decrease in time affordability. The locations of these areas can be seen in Figure 5.2. People living on the outskirts of the metropolitan have a range of different time affordability ratios.

Possible reasons for the scattered distribution include:

- Children spend a lot of time at home and increase the average disposable time of a household.
- People living in suburban areas have access to private transport, and therefore travel further because they can afford to do so.
- People living in poorly accessible destinations make less trips than people living in accessible destinations. Therefore, they have one long trip not multiple short trips. These multiple shorter trips may result in more time spent travelling than one long trip.

Time Affordability as a Function of Accessibility

Time affordability and accessibility have similar characteristics in terms of travel time. Mobility, a factor of accessibility considers the travel time to destinations. Time affordability looks at the percentage of time spent travelling to needs-oriented destinations. Therefore, there should be some sort of correlation between the two.

Figure 6.6 shows the results of plotting time affordability as a function of accessibility for the different household groups. The first graph corresponds to a single adult without children household, the second to a single adult with children household, the third to a multiple adult without children household and the last to a multiple adult with children household.

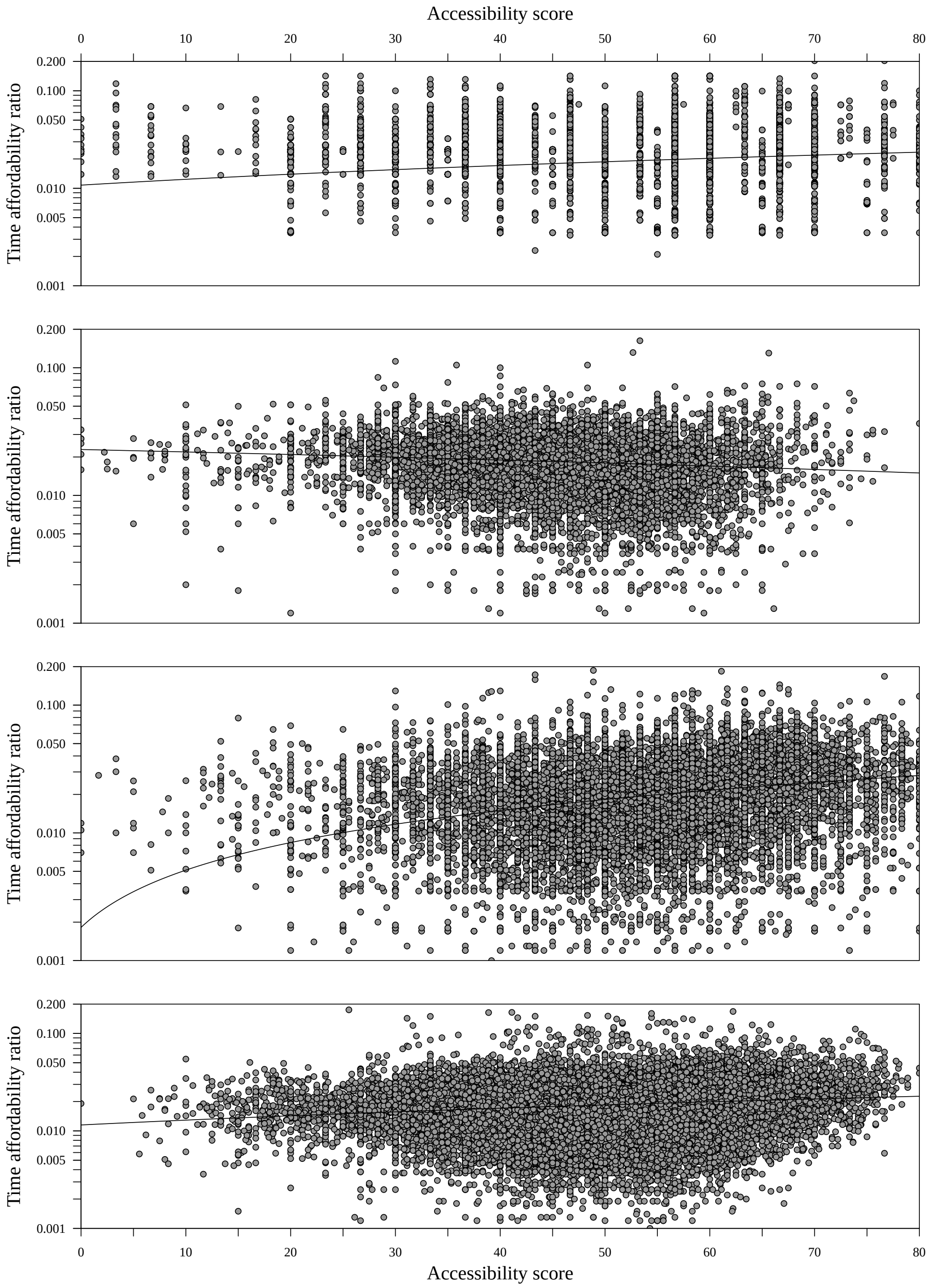


Figure 6.6: Time affordability ratios as a function of accessibility.

Table 6.5: Coefficients of determination.

Household Class	R^2
Single adult, no children	1.1900 %
Single adult, with children	1.0539 %
Multiple adults, no children	6.1729 %
Multiple adults, with children	1.7263 %

The coefficient of determination (R^2) is a measure of the degree to which the regression line represents the data and of the linear association between two variables (Math Bits, 2012). In this case, the variables are accessibility and time affordability. The more scattered the points are around the line, the more unexplained the variance is.

The acceptable measurement is usually between 60% and 100% (U.S Geological Survey, 2010). This can be explained by saying the closer the data points are to the regression line, the stronger the linear association between the variables.

The R^2 values of the above graphs are very low. Although there is a slight increase in time affordability as accessibility increases, the percentages indicate that there is minimal association between these two variables.

It is likely that there is minimum association between the two variables, due to the fact that accessibility consists of many different variables. Accessibility does not only look at time factors of transport, but also at the amount of transport options that are available. It is suggested that time affordability as a function of mobility be further investigated. At present, mobility is only available for individuals and not households. Therefore, when a mobility score is available for households, this relationship should be investigated.

Time Affordability Statistics

Table 6.6 provides the overall summary statistics of the time affordability of the sample population. The smaller the time affordability ratio, the better. This indicates that the household lives very near to all their destinations and spends minimal time travelling.

The 100^{th} percentile is not included in order to omit the extreme outliers. The 99^{th} percentile represents the maximum range. Single adults with no children households spend the largest proportion of time on transport, whilst single adults with children households spend the smallest proportion of their time on transport.

Table 6.6: Time affordability ratio for different household classes as a percentile.

		Time Affordability Percentiles					
Household class	**Mean**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
Single adult, no children	2.15%	0.00%	1.41%	2.75%	4.69%	5.88%	9.24%
Single adult, with children	1.85%	1.19%	1.72%	2.35%	3.02%	3.59%	5.03%
Multiple adults, no children	2.03%	0.74%	1.60%	2.71%	3.95%	4.80%	7.27%
Multiple adults, with children	1.87%	1.17%	1.65%	2.26%	3.01%	3.57%	5.26%

The results of the study done by Fan and Huang (2011) are slightly different to the above results. The percentage of time spent on travelling is in the same range, however the order of the largest household group that spends the most time travelling is different. The population used for this study was much smaller than that of the population statistics used by Fan and Huang (2011), therefore this would affect the distribution of results. Their study was done in the Twin Cities Metropolitan where there are 3.15 million people. The data sourced from the Nelson Mandela Bay Metropolitan Travel Survey of 2004, estimates the population at 1.1 million.

The various statistics are discussed in more detail below, with reference to the corresponding time affordability histograms for the different household groups.

Time Affordability Histogram Statistics

One time affordability histogram from each household group is discussed in detail. The histograms for each household group with the associated accessibility classes, Figures B.5–B.8, can be seen in Appendix B. Table 6.7 is a summary of the data that is represented by the time affordability histograms.

Table 6.7: Mean and median of time affordability ratios of household classes with associated accessibility rating.

Household class	**Accessibility**					
	Low		**Medium**		**High**	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Single adult, no children	1.82%	1.54%	1.28%	1.10%	2.15%	1.89%
Single adult, with children	1.96%	1.83%	1.70%	1.55%	1.84%	1.64%
Multiple adults, no children	1.51%	1.21%	1.62%	1.39%	2.34%	2.09%
Multiple adults, with children	1.76%	1.65%	1.72%	1.58%	2.07%	1.85%

The mean of each group is greater than the median, therefore all histograms are skewed to the right. Only a small percentage of households spend more than the mean. The time affordability ratios percentages are quite low, indicating that transport is affordable in terms of time. An example of a household that spends more than the mean is a person who works far from home and therefore spends a lot of time travelling to work. Depending on where a person lives, determines how long they have to travel to reach their desired destination.

In Table 6.7, it can be seen that when the accessibility of the household increases from low to medium to high, the mean does not follow a pattern of either increasing or decreasing. It would be expected that as accessibility increases, the time affordability ratio would decrease as people live nearer to facilities. However, this is not always the case. Possible reasons include:

- Households living in highly accessible area have a higher income, therefore the household travels more. They might travel further to work or drive the children to school because they can afford to do so. They choose to spend more time travelling, which increases their time affordability ratio.

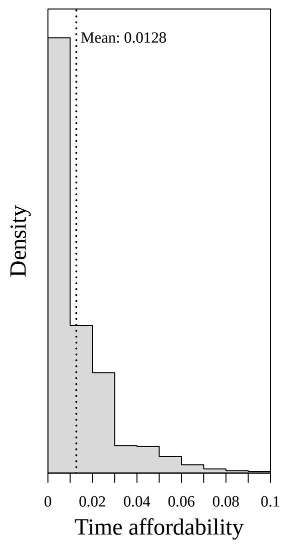
- Some households have adults who do not work and spend most of their time at home, which decreases the time affordability ratio.

- Children spend most of their time at home, at school in after-care or doing extramurals. Therefore, they tend to travel less than adults, which decreases the time affordability ratio of the household.

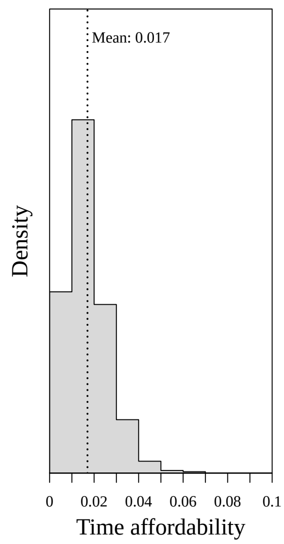
- OpenStreetMap was used, which may not be accurate, resulting in people being simulated as travelling longer than they actually do.

6.2.4 Time Affordability Histograms for Households with Medium Accessibility

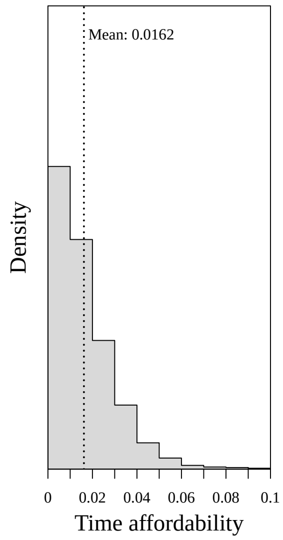
Figure 6.7 is the time affordability histograms of the household groups for a medium accessibility rating. These histograms were chosen to discuss as they demonstrate the distribution of the time affordability results well. The histograms for the remaining accessibility ratings can be seen in Appendix B.2.



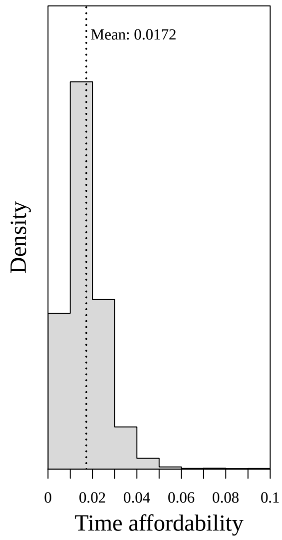
(a) Single adult, no children household



(b) Single adult, with children household



(c) Multiple adults, no children household



(d) Multiple adults, with children household

Figure 6.7: Time affordability ratio histograms of households with medium accessibility.

A *single adult with no children household* with medium accessibility has the smallest time affordability ratio. There is only one person living in this household, therefore the majority of their travelling time goes towards travelling to work during the week. It is likely that when they have to buy groceries, they stop at shopping centres as part of their trip home, decreasing the time affordability ratio.

A *single adult with children household* spends a larger proportion of time on transport than a *single household with no children*. For medium accessibility areas, children have to be driven or use public transport to reach destinations that are further away from the household. If the people living in this household do walk the long distances to destinations, they spend more time travelling, increasing the time affordability ratio.

A *multiple adult with no children household* spends a larger proportion of time on transport than a *single adult household with no children*. It is likely that one adult may have a full-time job and the other adult in the household only has a part-time job. The adult with the part-time job spends more time driving to destinations to participate in various activities, which increases the time affordability ratio.

A *multiple adult with children household* spends a larger proportion of time on transport than a *single household with children*. There are more people in the household that have to travel. Parents may have to drive the children to various activities, as well as travel to work on a daily basis. The adults in the household may not all work full-time and therefore spend more time travelling in their spare time, increasing the time affordability ratio.

The majority of *single adult with no children households* and *multiple adults with no children households* have a ratio between 0% and 1.0%, indicating that most of these households do not spend an excessive amount of time travelling.

The majority of *single adult with children households* and *multiple adults with children households* have a time affordability ratio between 1.0% and 2.0%. This interval and the means are higher than when there are no children in the household. Children increase the median values of the time affordability ratios, thereby increasing the distribution of half the households. This percentage is still considered low and affordable in terms of time.

Time Affordability Findings

Time affordability cannot be directly linked to accessibility. There is no clear pattern of how time affordability changes between different households. This is due the fact that various households' time is dependent on their personal schedules, since people fill their days with different activities. Someone who works part-time might choose to buy groceries on a daily basis and spend more time travelling, whilst another household who works full-time is more likely to only go to the shops once a week. Therefore, a household's time affordability is increased due to personal preferences.

In South Africa, the type of households are very diverse. There are often cases, especially in low-income households, where the extended family live together. Therefore, grandparents who are retired often live in the same household as their employed children. These people do not spend as much time travelling as employed people. Consequently, they lower the household percentage of the time spent travelling, contributing towards the scattered time affordability ratios.

The diversity of households and their personal preferences makes it very difficult to set a standard of what time affordability ratio is acceptable. The reasons behind a household's time affordability is difficult to understand. Transport could be too expensive and not accessible, and they have to walk, which is very time consuming. Or, the household chooses to spend more time travelling, due to the fact that they wish to fill their day with various activities. At this point in time, it is concluded that the closer the time affordability ratio is to zero, the better.

Chapter 7

Conclusion

A metric for the accessibility and affordability of transport in South Africa has been developed. This allows for a tool to measure the impacts of transport policies. The metric consists of three parts: an accessibility measurement, an income affordability ratio and a time affordability ratio.

In order to improve the transport system, strategies can be implemented in an area. The effect on the affordability ratios will indicate how affordable the proposed changes of transport would be.

7.1 Assumptions

Assumptions had to be made in order to calculate accessibility and affordability, which would have had an impact on the results. It was assumed that the average walking speed is 0.8333 m/s. Due to the fact that an average was used, some people may walk slower and others faster, therefore the results of accessibility may have affected the accuracy of a household's accessibility rating.

Travel time was measured from the home to the desired destination. This was assumed for the purpose of consistency. However, in reality people travel from home to a destination and then to another destination. For example, from home to work, then to a shopping centre and then back home. This assumption would have affected the accessibility ratings and time affordability ratios results.

Households with no income were removed from the affordability results due to them skewing the results incorrectly. These are the households that have a problem with transport affordability. They are only able to walk to their destinations, as they cannot afford to purchase any mode of transport.

The private transport running costs were taken as a R2.53 in the calculation of the income affordability ratio. In reality people have different types of cars and fuel consumptions, therefore running costs may have been underestimated or overestimated for households.

The current metric does not consider how the disabled are affected by transport accessibility or affordability. It is assumed that all people are able to walk. This is not an accurate reflection of society, and therefore should be accommodated for in the metric when this data is available.

7.2 Overall Findings

The accessibility of transport can be clearly defined, and there are distinguishable patterns that can be seen in the spatial representation. The spatial representation of accessibility gave evidence of the fact that suburban areas experience high accessibility of transport, whilst remote areas, such as the township areas, experience low accessibility. To improve these areas, facilities need to be built that increase the accessibility in the area, or transport needs to be improved by increasing the availability of different modes of transport.

Affordability is a difficult concept to define. Distinct patterns in the spatial representation of the income affordability ratios could not be seen. The fact that many people spend more than what they earn, often purchasing on credit, makes it difficult to define the actual income resources of a household. Either the metric needs to be adjusted for affordability, or affordability is different from household to household.

Similar to the income affordability ratios, the time affordability ratios do not have distinct patterns. As the accessibility of households increases, many seem to spend more time travelling, which is counter-intuitive. It could be that when households earn more, they are willing to spend more in order to better their quality of life. An example of this concept is a person who drives to a more upmarket shopping centre that is far away, instead of walking to the closest one. The higher the income of the household, the more likely they are to buy a more expensive car, or live in a nicer area and have to travel further. This increases their transport expenditure, as well as the amount of time that they spend travelling. This could be that if people can afford it, they travel more. Therefore, time affordability is very dependent on a person's personal schedule and preferences, making it difficult to determine a standard for the household time affordability ratio.

7.3 Recommendations

Waiting time for transport and the number of trips that need to be taken in order to reach the desired destination should be added to the accessibility matrices once the data is available. This will improve the accuracy of the accessibility rating.

The results of the Census of 2011 will be made available at the end of 2012. It is recommended that once this data is available that the synthetic population model is updated so that the metric will provide more accurate measurements.

Households that spend more than what they earn affects the results of the income affordability ratio. It is difficult to know exactly how much debt households have and the degree to which they spend more than they earn. Depending on the people in the household, certain households may save but others are likely to spend over their budget. This makes affordability much more difficult to measure as the circumstances of each household vary to a large degree. It is recommended that the household expenditure, instead of the household income, is investigated as a ratio to measure affordability.

Although children can contribute to the household time affordability, they are usually dependent on their parents for transport. Children go to school and then work at home, therefore they skew the time affordability by indicating that the household has more disposable time than is accurate. If they do not walk to their destination, an adult may drive them to their destination. Therefore, the transport expenditure for children will be accommodated for in the adults transport expenditure. It is recommended that in future, the affordability of the household excludes children, and focuses on the adults' time usage and income. This will give a better indication of the affordability of the household.

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Appendix A

Tables in Appendix

Table A.1: Various types of commuters in South Africa (Venter, 2011).

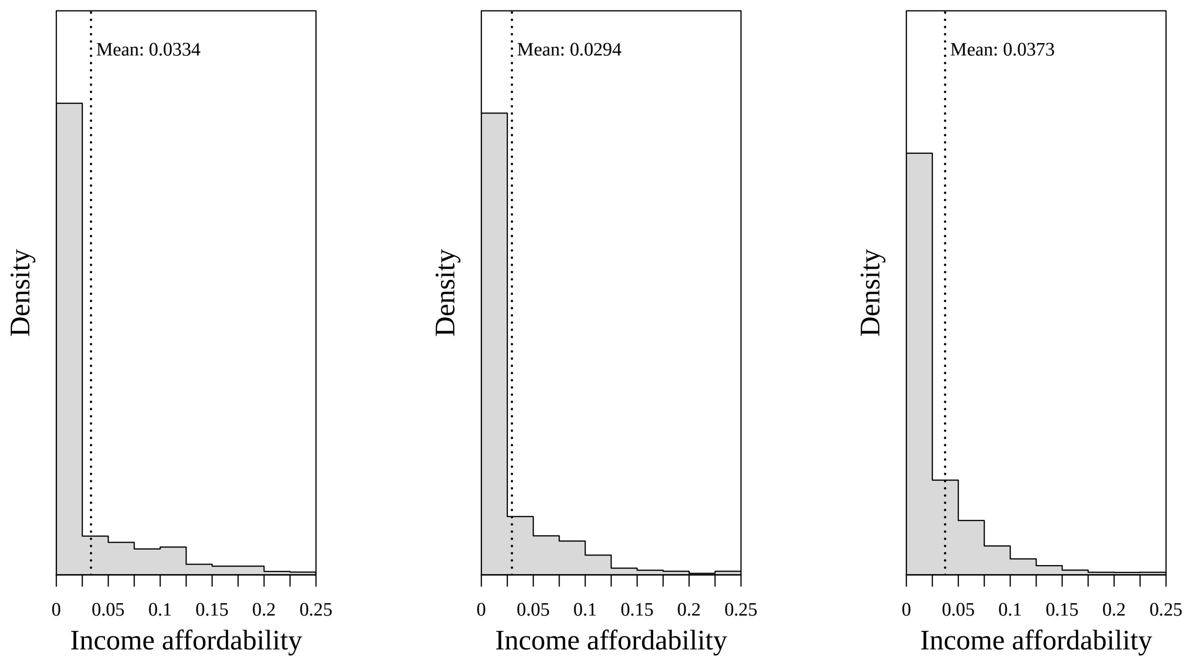
Commuter Types	**Percentage**	**Average cost per trip (R)**	**Average monthly income (R)**
Short distance walkers	17%	0.00	1545.00
Long distance walkers	13%	0.00	1198.00
Low-income public transport users	17%	3.81	841.00
Medium-income public transport users	17%	4.88	2657.00
High-income public transport users	1%	5.62	7878.00
Medium-income car passengers	7%	1.13	1980.00
Medium-income car drivers	15%	34.77	3158.00
High-income car users	11%	35.66	11177.00
Long distance car users	2%	52.89	4386.00

Source: This table is adapted from The National Household Travel Survey 2003

Appendix B

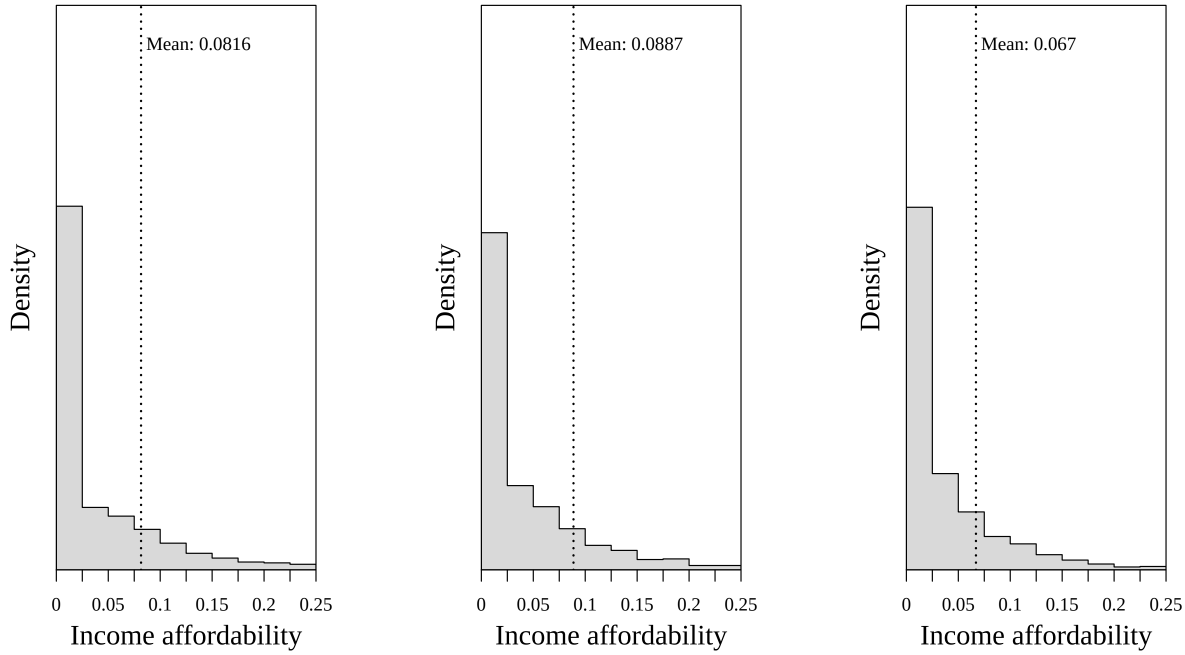
Graphs in Appendix

B.1 Income Affordability Ratio Histograms



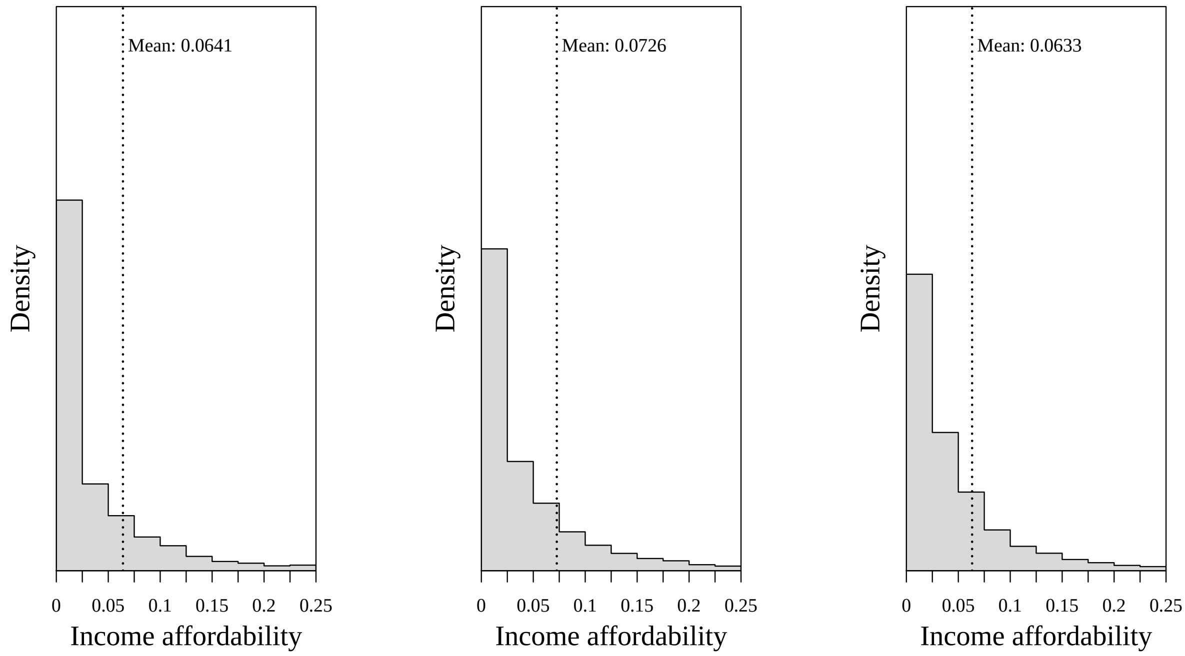
(a) Low accessibility (b) Medium accessibility (c) High accessibility

Figure B.1: Income affordability histograms of households with a single adult and no children.



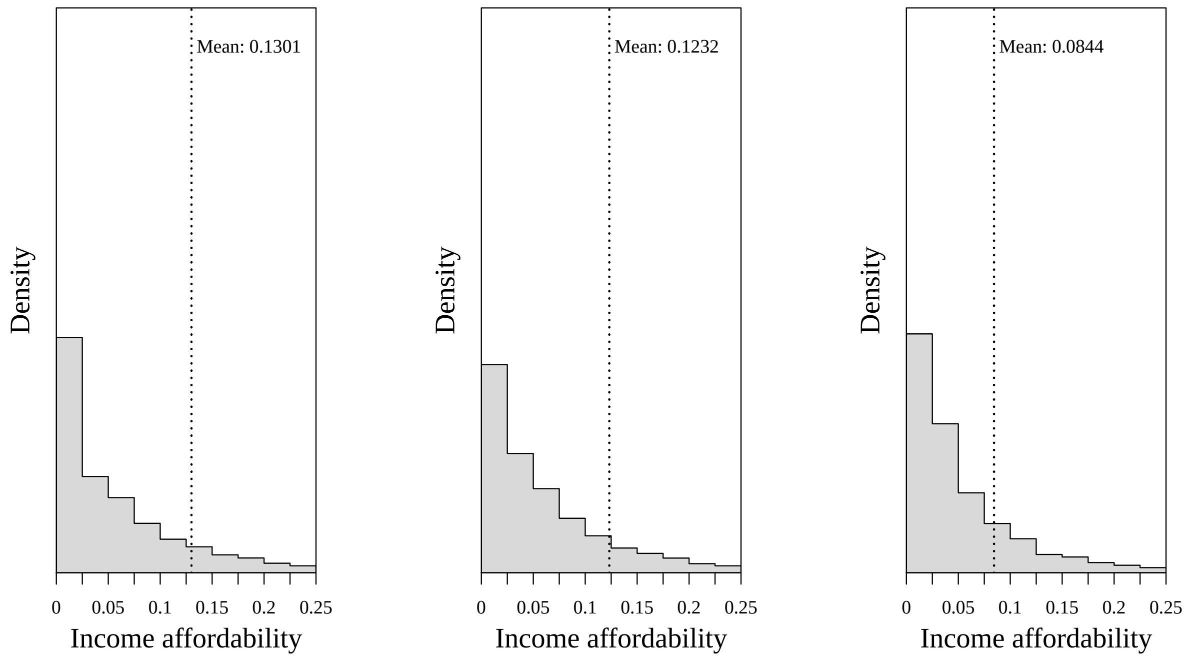
(a) Low accessibility (b) Medium accessibility (c) High accessibility

Figure B.2: Income affordability histograms of households with a single adult with children.



(a) Low accessibility (b) Medium accessibility (c) High accessibility

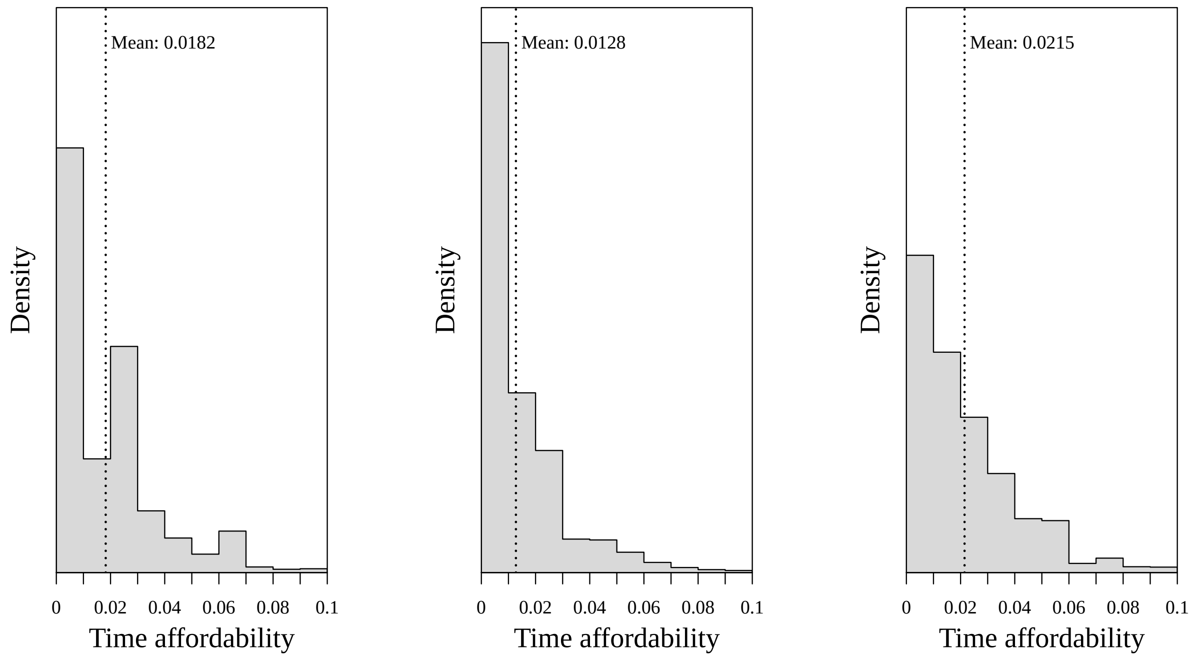
Figure B.3: Income affordability histograms of households with multiple adults with no children.



(a) Low accessibility (b) Medium accessibility (c) High accessibility

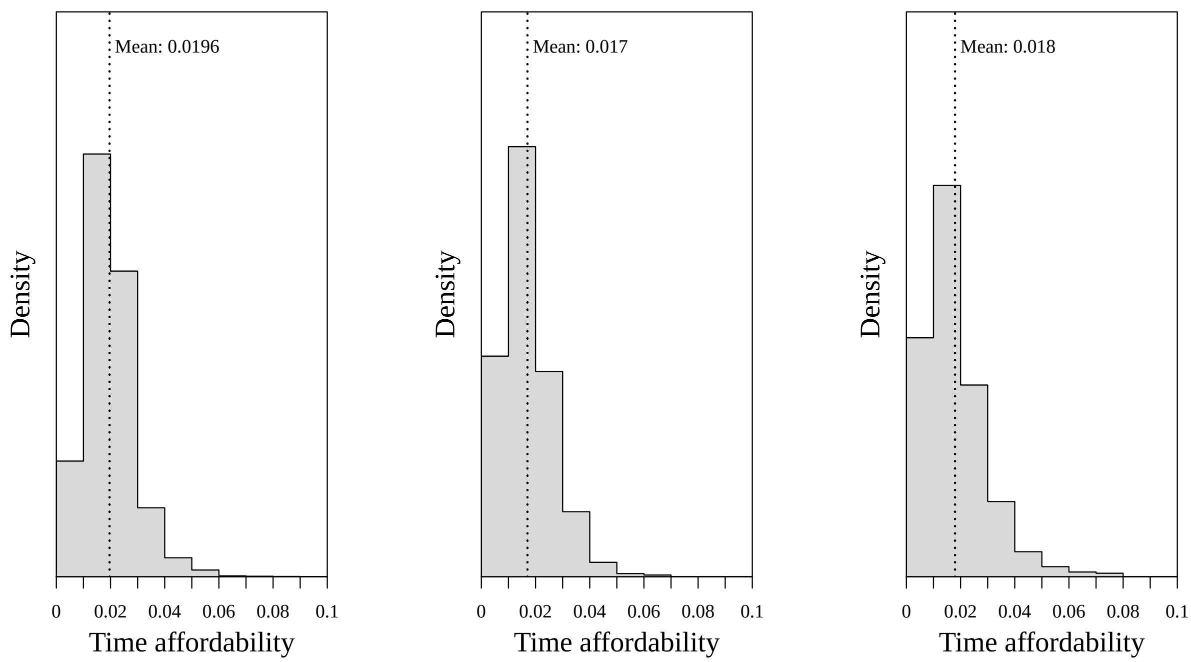
Figure B.4: Income affordability histograms of households with multiple adults with children.

B.2 Time Affordability Ratio Histograms



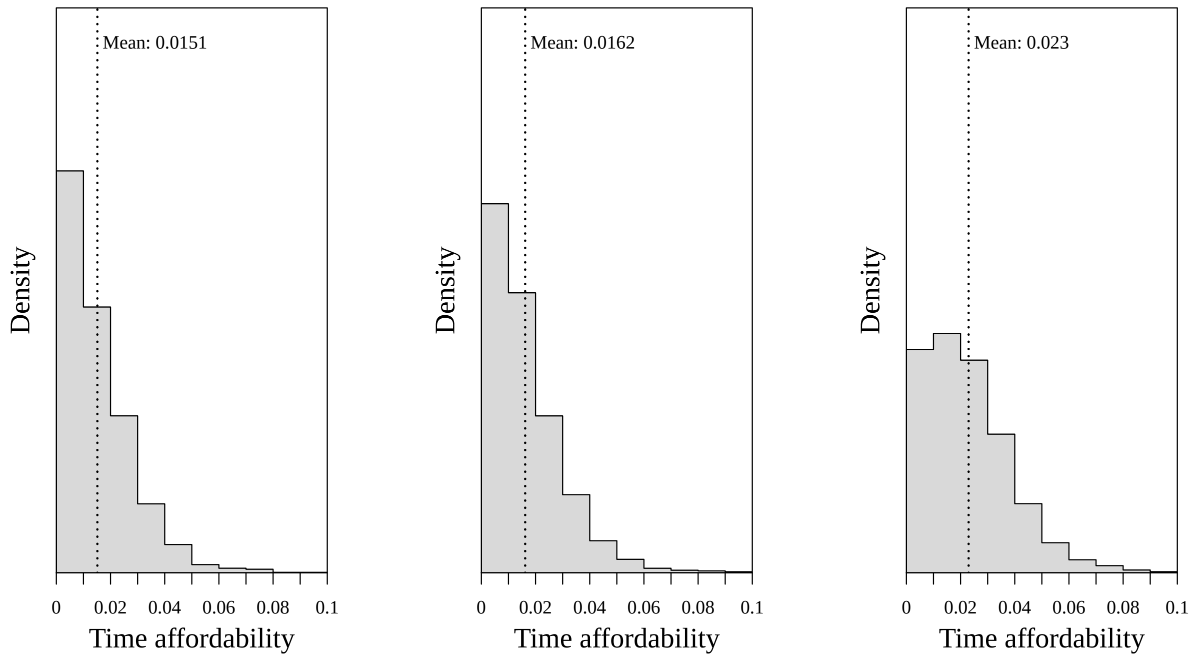
(a) Low accessibility (b) Medium accessibility (c) High accessibility

Figure B.5: Time affordability histograms of households with a single adult and no children.



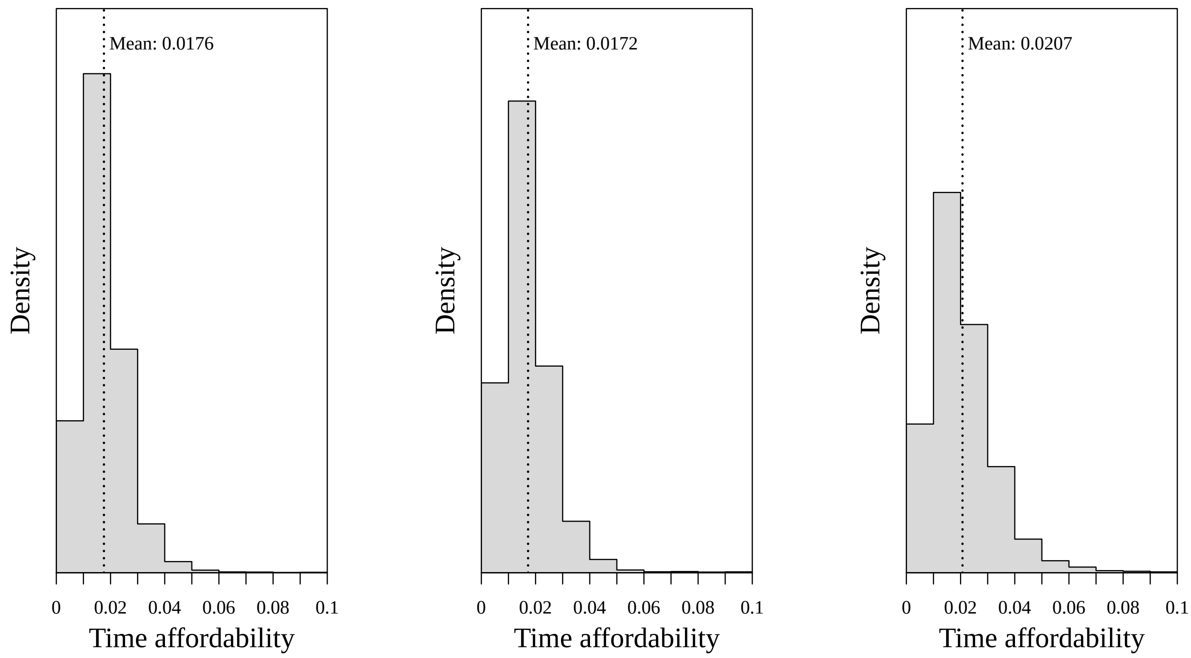
(a) Low accessibility (b) Medium accessibility (c) High accessibility

Figure B.6: Time affordability histograms of households with a single adult with children.



(a) Low accessibility (b) Medium accessibility (c) High accessibility

Figure B.7: Time affordability histograms of households with multiple adults with no children.



(a) Low accessibility (b) Medium accessibility (c) High accessibility

Figure B.8: Time affordability histograms of households with multiple adults with children.

B.3 Time Affordability Results of Fan and Huang (2011)

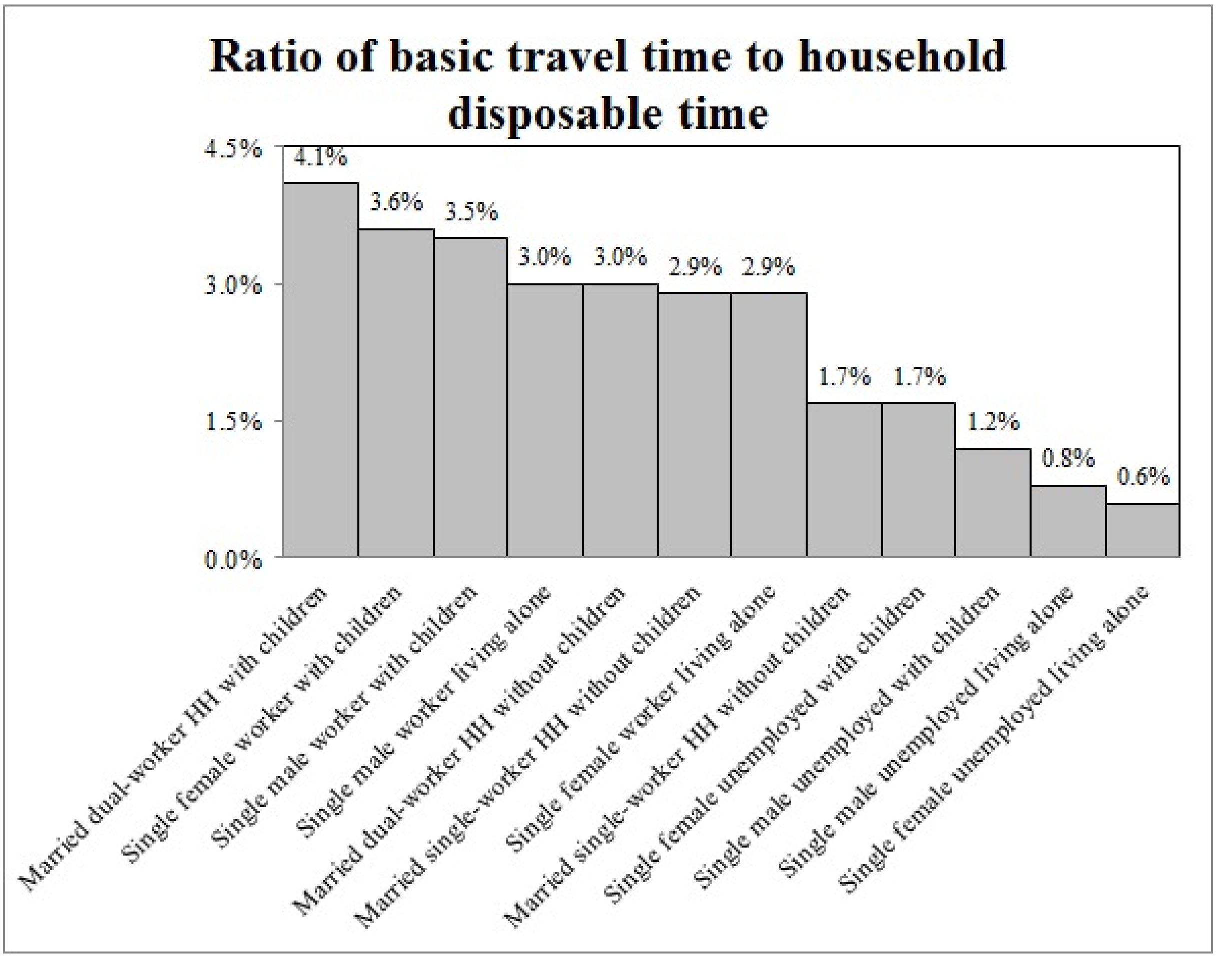


Figure B.9: Results of time affordability by Fan and Huang (2011).