Student Housing Location Preferences: a Suitability Analysis Implementing the LSP Method

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Summary

The Netherlands is considered one of the countries with higher population density in the world, this characteristic makes its real estate market one of the most interesting for investors. In recent years, developers have shifted their attention from regular housing projects towards a very especial type of real estate asset: student housing. Purpose Built Student Housing (PBSA) are projects developed around the needs, necessities and desires of students (typically bachelors and masters). This type of constructions are the market response to the historically high student housing demand that several cities in the Netherlands face. In different cities there are many PBSA projects under construction or planned for the upcoming years, however, according to data from consultancy firms, investments are being made mostly in big student cities like Amsterdam, Groningen, Utrecht, Eindhoven, etc. This situation pose an interesting condition for investors, municipalities and universities in medium sized cities because if they want to keep attracting students to their regions they will have to provide student housing options. PBSA's have been analyzed by several authors in many previous research, however most of these studies focuses on the building characteristics itself. The scope of this research is the student housing location preferences and it focuses on the definition of compulsory and desirable location attributes in PBSA's. The importance of identifying preferred student location attributes relies on the planning for such developments, where if an investment will be made, shareholders must assure that their target market will be satisfied with the offer.

The scope of the research resulted in the following main question: what location factors are important in student's preference regarding PBSA, and how these factors can be included in a land suitability analysis? Hence, the study objectives can be summarized in two: the definition of location attributes that student's care about and its importance level, and the application of a methodology to pinpoint best locations based on the relevant location attributes.

To understand the student's preferred location attributes a survey was prepared. This questionnaire was distributed among 1453 people and was completed by 509. In this survey 12 location attributes were assessed. These 12 attributes were grouped into three categories:

accessibility, amenities and population. The evaluated attributes were: distance to bus stop, main street, airport, train station, green area, sport center, health care center, supermarket, city center, university, average neighborhood age and average neighborhood density. The selection of such attributes was based on literature review of previous research. In the survey, respondents were asked to assess the importance level of such attributes, as well as, match them through a pairwise comparison to obtain the attribute's overall weight in the decision making process.

From the survey results, it was possible to draw certain conclusions about the assessed attributes. Criteria regarding amenities and population have a high importance level for students, while population characteristics has a low influence level. Regarding the accessibility criteria, proximity to a train station is the most important accessibility attribute, followed by distance to a bus stop. Distance to a main street or an airport were considered of less importance by the sample. For the amenities attributes, proximity to a supermarket, city center and a university were considered by respondents the most important attributes, while distance to green area, sport centers and health care facilities have certain importance for students but they were evaluated with a lesser importance rank than the previous. With reference to the population criteria, both attributes, average neighborhood age and density were appointed with a very low importance level for students.

With the information acquired through the questionnaire results it was possible to implement a Multi Criteria Evaluation (MCE) method capable of developing suitability maps taking into consideration all the aforementioned attributes and its importance level. The selected method was Logic Scoring of Preferences (LSP). The LSP method is capable of developing a suitability analysis by taking into consideration mandatory and non-mandatory attributes of the decision process. To construct a PBSA suitability map, a location had to be appointed. The city of Tilburg was selected because of its increasing student population, as well as its null PBSA construction plans. 3 different PBSA suitability maps for the city of Tilburg were prepared. In the first map, all 12 attributes were incorporated into the map construction process. In the following, the population criteria was removed because of its very low significance level. The last map was developed to show a possible scenario, where unsuitable regions become suitable by the addition of certain attributes that previously were not found in the area.

Regarding the suitability map developed using all the 12 assessed attributes, the best areas to construct PBSA projects are around Tilburg's city center, where all the mandatory attributes appointed by students are located. With reference to the suitability map where only accessibility and amenities criteria were occupied, the results were very similar to the previous map; this behavior can be explained by the fact that the population information input was not of great detail, generating oversimplified population inputs which at the end were not useful for the classificatory intent of the LSP method. With regards to the last suitability map, a proposal to develop Tilburg's west region was made by focusing on the development of mandatory amenities attributes, such as supermarkets, city center environment and universities. By adding these attributes to the west side of the city it was possible to generate a suitable region to develop PBSA's projects. From the development of these three suitability maps it was possible to conclude that mandatory attributes have a high impact in the suitability of a region, whereas non-mandatory attributes also present certain weight in the decision making process, its non-fulfillment would not mean that a location is unsuitable, whether non-fulfilment of mandatory attributes would automatically classify the region as unsuitable.

The LSP method allows the decision maker to model more complex suitability maps, where mandatory and non-mandatory attributes can be considered without losing significance of each. As of now, this method has not been fully implemented in any computational package, therefore, extra effort and computation time is needed for modelling suitability maps using this specific method. Regardless of this, it is recommended to use the LSP method in future student housing location suitability research.

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Preface

The following report presents my master thesis for the completion of my study Construction Management and Engineering (CME) at Eindhoven University of Technology (TU/e). The graduation project was conducted as a combination of desk and field research in the cities of Tilburg and Eindhoven in the Netherlands.

The fulfilment of my research would not have been possible without the advice, support and cooperation of others. Therefore, I am grateful and wish to thank everyone who offered help. For their guidance, support and enthusiasm I like to thank my supervisors Dr. Ing. P.J.H.J. Peter van der Waerden and Dr. Qi Han. They were always willing to share their knowledge and give feedback when needed, as well as for their time and precise annotations that shaped this research. Additionally, I like to thank all the people who took the time to fill in my survey, without their input it would not have been possible to complete this thesis.

Overall, I enjoyed working on my master thesis and I found my research subject very interesting and useful in the real estate market. I hope you will find it interesting too and enjoy reading it.

Shai Corrales

Eindhoven, August 2017

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Glossary

A	Arithmetic Mean
AHP	Analytical Hierarchy Process
C	Full Conjunction
CI	Consistency Index
CPA	Conjunctive Partial Absorption
CPL	Continuous Preference Logic
CR	Consistency Ratio
D	Disjunction
GCD	General Conjunction/Disjunction
GIS	Geographic Information Systems
HPC	Hard Partial Conjunction
HPD	Hard Partial Disjunction
LPS	Logic Scoring of Preferences
MAUT	Multi Attribute Utility Theory
MCDM	Multi Criteria Decision Making
MCE	Multi Criteria Evaluation
OM	Outranking Methods
OWA	Ordered Weight Average
RI	Random Index
SAW	Simple Additive Weighting
SPC	Soft Partial Conjunction
SPD	Soft Partial Disjunction
WPM	Weighted Power Mean

CHAPTER 1

Introduction

1.1 Introduction

The Dutch real estate market has traditionally being very profitable for investors, and more recently, since the third quarter of 2013 the amount of Dutch house sales has risen steadily averaging a 25% increase each year (Savills World Research, 2016). Home buyers in the Netherlands are taking advantage of historically low interest rates and an increased consumer and producer confidence; these factors have caused a rush of foreign and national investors into the Dutch market.

While there is a notorious housing boom in The Netherlands, in the last few years there has been an interest growth from domestic and international investors on student housing. This interest has resulted in new developments, redevelopments schemes and several turnkey properties. The main reason of this interest relates to the student housing supply shortage that has not been able to keep up with the increasing number of students. This shortage is not expected to decline in the near future as the amount of students is projected to continue to rise. According to official publications the number of students at universities will continue to grow (Hulle, 2015).

The non-stop increase of students represents a situation where offer is lower than demand. If real estate companies, developers and investors want to take advantage of such position to construct student housing buildings, as well as municipalities want to keep up attracting students into their regions, it is important to notice where the biggest student housing markets are, what the expectations for such locations are and which areas within such markets are the most suitable to develop student housing.

1.2 Background

Regarding how students are distributed in the Netherlands; the largest student city is Amsterdam with an approximate of 108,000 students, Rotterdam is the next on the list with 86,500 enrolled students, followed by Utrecht (72,000), Groningen (54,500) and Eindhoven (54,000). Additionally, cities like Tilburg, Arnhem, Enschede, Leiden, The Hague, Delft, etc. have registered a total number of 20,000-40,000 students per city (Savills World Research, 2016). In the country, there are 15 research universities and 37 universities of applied sciences spread over 25 cities. At research universities, the 2022 forecasted number of students is 259,000 (4.6% increase) and at universities of applied sciences 454,200 (2.2% increase) (Hulle, 2015). This increase in the student quota takes into account international students, which in the last few years have become a very important niche to many Dutch universities. According to EP-NUFFIC, over the last 10 years, the number of international students went from 41,200 to 77,900, this represents an increase of almost 90% (CBRE, 2015). This gain in international students can be attributed to the amount of English taught Masters and Bachelors programs, combined with the reasonable tuition fees for EU students. Of the total student population, international students account for 10.7% and, in research universities, the share of international students stands at 16.2% (CBRE, 2015).

In the Dutch educational system, universities are funded on the basis of number of students, therefore universities promote themselves, even in foreign countries, so it is safe to assume that growth of international students will continue as Dutch universities keep promoting themselves, tuition fees remain low and the number of English-taught courses keep increasing.

In relation to student housing expectations, traditionally, the demand for student rooms was characterized by small household sizes and low income levels, these characteristics used to limit the potential housing supply to small sized accommodation with shared facilities and low rental levels. However, since the abolishment of housing allowance for rooms with shared facilities (end of the 90's), the market has shifted towards self-contained student units (Savills World Research, 2015).

Apart from the market shift caused by the abolishment of rental allowance for rooms with shared facilities, there is another factor that boosted this transformation: the change of needs and desires of the millennial student. Demographers define the millennial generation as the children who were born between the early 1980's and early 2000's, they have an increased use and familiarity with communications, media and digital technologies as well as a liberal approach to politics and economics (Horovitz, 2012); regarding student housing, millennials have a strong tendency towards lifestyle branded apartments, where amenities and social areas are an integral part of the building design, connectivity and accessibility (Deninger, 2016). The magazine "University Business" identified 6 trends in modern student housing: luxury, privacy, privatization, live and learn, safety and security and go green. The interest for housing with amenities has increased and what once was considered as luxuries (kitchens, private bedrooms, private bathroom, social spaces, lounges, etc.) now is expected and in some cases required (La Roche, Flaningan, & Copeland, 2010).

With the increase in the quality of student housing it is possible to observe a higher willingness to pay higher rental fees; official data shows that in only 3 years, from 2012 to 2015, a 65% of the students were willing to pay more than €400.00 per month for rooms with own facilities, while in 2012 only 40% of the students were willing to pay that amount, and the preference for a self-contained room dropped from 35% to 5% in the same time frame (Hulle, 2015).

In the Netherlands, in past years, the gap between demand and supply of student housing was enormous, however, this started to change since 2012 when several developments were delivered and the national government eased some of its regulations to induce the construction of Purpose Built Student Accommodations (PBSA) (Savills World Research, 2015). PBSAs are developments that were designed with one purpose: to satisfy all the requirements and needs that a bachelor/master and, in some cases, PhD students have; in the last years PBSAs have become one of the most interesting real estate investments in countries like UK, USA among others (Hayman, 2015). The interest from investors in PBSAs can be also seen in the Netherlands, currently many developments are being built in major cities such as Amsterdam, Groningen and Utrecht, but according to the 2016 Student Housing in the Netherlands report, filed by the consultancy firm Savills, there are some important cities where PBSAs are underdeveloped or non-existent.

Underdevelopment of student housing pose a specific market scene where the amount of available student housing facilities is far shorter than the number of students looking for a place to rent. This situation can be seen as an opportunity for developers and real estate companies to construct PBSA’s to further improve their investment portfolios, as well as for municipalities and universities to keep attracting students into their regions. However, to construct PBSA’s it is important to understand what the most important attributes for such buildings are, regarding intrinsic building’s characteristics as well as location attributes.

1.3 Aim and research questions

The previous section has shown the relevance and importance of student housing in the Dutch real estate market, as well as the market shift towards self-contained units which have forced developers to invest on PBSA’s. This research aims to improve the PBSA understanding, focusing on location factors influencing student housing preference.

The scope of this study is the student housing preferences. This research focuses on the definition of compulsory and desirable location attributes in PBSA’s as well as a methodology to pinpoint the best areas to construct such developments. This resulted in the following research question:

What location factors are important in student’s preference regarding PBSA, and how these factors can be included in a land suitability analysis?

To be able to answer this question a set of sub-questions have been formulated:

1. What are the location attributes that student’s care about?
2. What is the level of importance of such location attributes?

3. What method, that includes all of the student's location preferences as well as its importance levels, should be used to develop a land suitability analysis?
4. How to implement such method?

In the remainder chapters of this paper, the research questions and sub-questions formulated previously will be answered and properly discussed. The next sections of this chapter provide the reader a guide of how the research was conducted, as well as a structure to better understand this report.

1.4 Research structure

In this section, an overview of all the steps followed to answer the research question and sub-questions will be discussed. The research started by the definition of the research's aim and objectives which led to an extensive literature review. The literature review was focused on residential mobility, housing choice and preference, student housing and multi criteria decision methods. Based on the literature review, it was decided to select the Logic Scoring of Preference (LSP) method to assess the research's questions. The LSP method requires inputs that relate to the attribute's importance and weight values, which can be either obtained from other papers or through a survey. For this research, it was decided to create a questionnaire, in which a specific set of attributes was selected to be assessed by respondents. A very important part of the survey relates to the pairwise comparison of the selected attributes; this process allows to obtain weight values for each attribute which later can be used to develop a suitability map. After the survey was prepared, it was distributed and the results were analyzed. From these results, LSP inputs were obtained and the method was implemented. The implementation of the LSP method allowed the creation of suitability maps that help with the identification of suitable regions for certain type of developments. For this research, Purpose Built Student Accommodation (PBSA) suitability maps for the city of Tilburg were created. The complete research process is depicted in figure 1:

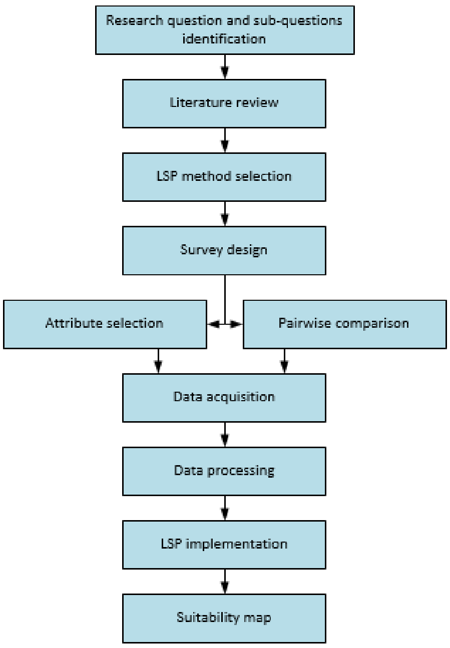


Figure 1. *Research structure*

In the following chapters a thorough explanation of each of the followed research steps will be presented and explained.

1.5 Report guide

This research's report is structured into 8 chapters. Chapter 1 introduces the research followed by literature review which covers chapter 2 and 3. Chapter 2 will first review literature regarding housing, preferences and student housing. Chapter 3 will then address the literature regarding Multi Criteria Decision Making (MCDM) to evaluate student housing preference behavior. Afterwards, chapter 4 will discuss the research design and gives an overview of the research approach. This is followed by data collection in chapter 5, where the survey and sample will be discussed. Then, on chapter 6, the implementation of an MCE method is disclosed. Other suitability maps derived from chapter 6 are discussed in chapter 7. Chapter 8 will elaborate the conclusion of this research and its implications, as well as advice and limitations for future studies.

CHAPTER 2

Housing Preferences and Student Housing

2.1 Introduction

Housing and housing preference behavior have been studied extensively for many years. Researchers have focused on many different aspects of this broad theme. What is housing? Why do people move? In the first section of this chapter, these questions will be answered.

Even though this paper focuses on students, the theory background of residential mobility is applicable for the main aim of this research. Therefore, in the second part of this chapter an overview of the variables that can influence housing preference behavior will be discussed, as well as models that can predict such behavior.

In the last section student housing will be addressed; a worldwide overview of the situation will be discussed slowly moving towards student housing in the Netherlands.

2.2 Housing and residential mobility

Housing is a very specific type of product with unique definition and characteristics. A house is a place to live in, but it is also a shelter for sleeping eating and protection. A house can facilitate daily activities (work, shopping) and social contacts (interact with neighbors, family and friends) and can be seen as a consumption product and investment good (large spending, symbolic meaning) (Jansen, Coolen, & Goetgeluk, 2011). Other authors argues that housing should be viewed as a collection of characteristics that are used to satisfy goals, such as comfort and esthetics (Maclennan, 1977); Bourne (1981) considers the immense psychological importance of housing for satisfaction, status, privacy, security and equity as well as its function as intermediary in the consumption process. Over all, these authors mention various functions of a house:

1. A center of shelter and personal care: sleeping, eating, privacy, protection, etc.
2. A center of domestic activities: activities related to work, leisure and social life.
3. Accommodating daily external activities such as work, shopping, etc.
4. Accommodating social contacts; a base for social activities.
5. A durable and costly financial consumption good as well as an investment good for owner-occupiers.
6. A durable and costly social consumption and investment good, which is related to the symbolic meaning of house and home on a personal and social level.

Housing is a special type of good that makes the market for dwellings a special type of market. Housing is highly expensive, spatial immobile, highly durable and multidimensional heterogeneous and physically modifiable (Galster, 1996). Housing is a dominant category of household expenditure that contains elements of both consumption and investment, at least for homeowners (Maclennan, 1977), however, the uniquely large housing rental market gives rise to a tenure choice decision that depends on both consumption and investment considerations; changes in occupancy are particularly costly: the considerable search warranted by the extreme heterogeneity and immobility of dwellings, the complex legal and other transactional services and the household move itself require a heavy outlay of time, effort and money, hence residential mobility is a rare event, as most households do not move often (Coulter, Ham , & Feijten, 2010). A relatively strong trigger or potential trigger is needed to actually decide that one wants to move.

Residential mobility is another topic that has been heavily studied through the years. Classical theories of mobility posit that people move different distances for different reasons (Coulter, Ham , & Feijten, 2010). In this framework, people are thought to migrate long distances across labor market boundaries primarily to obtain higher wages or to improve their skills and employment prospects (Böheim & Taylor, 2007). In contrast, less disruptive short-distance moves are thought to be driven by household transitions, dwelling and neighborhood preferences or social mobility aspirations (van Ham, 2002) Residential moves thus act as an adjustment mechanism allowing people to adapt to the new seeds and preferences generated by changes in their life course careers (Clark & Ledwith, 2006).

Several studies have been performed to investigate the types of moves that different people make at different stages of their lives. For example, it has been stated that young singles migrate frequently and tend to flow to urban centers offering high density of educational, employment and social opportunities (Dennett & Stillwell , 2010). This tendency to move, especially long distances, drops with age and as people accumulate “commitments”, such as an employed partner or children, which makes moving more complex and costly (Feijten , 2005). Afterwards, some pulses of residential mobility have been identified with health and care need purposes (Duncombe , Robbins, & Wolf , 2001).

Analyzing why people desire to move and how this impacts on their subsequent moving behavior has the potential to enhance our understanding of residential mobility motivations, however, little is known about the underlying reasons of such behavior because previous studies focus only upon self-reported reasons, which overlooks the large proportion of moving desires that are never followed by a residential move (Coulter, Ham , & Feijten, 2010).

These underlying moving reasons have an important role in the moving decision making process, however, it has been suggested that some types of moving desires have a greater likelihood of being acted upon than others; in general, it is likely that desiring to move in order to make urgent, major and targeted changes across life course careers is more likely to lead to actual mobility than desiring to move because of more diffuse feelings of dissatisfaction (Coulter, Ham , & Feijten, 2010).

So far, non-dissatisfaction residential mobility causes have been discussed, nevertheless, the classical view of residential mobility is that the decision to change residence can be seen as a function of the household's dissatisfaction with the present housing situation (Brown & Moore, 1970).

According to the classical mobility literature, residential stress is thought to be the trigger for residential mobility. Residential stress is experienced when a household is dissatisfied with its dwelling. Residential dissatisfaction is in turn the results of a discrepancy between actual and desired housing situation (Mulder, 1996). Residential satisfaction is found to be influenced by objective physical housing and environmental characteristics, demographic characteristics, social contacts in the neighborhood and psychological variables such as feeling and values (Bell, Greene, Fisher, & Baum, 2001).

The act of moving reduces the difference between desired and actual housing situation and is therefore expected to reduce stress (Coulter, Ham , & Feijten, 2010). However, moving is an indirect response to residential stress; the direct response to residential stress are moving wishes, representing pure housing preferences; whether people actually move will also depend on opportunities and constraints.

Constraints and opportunities are subjective concepts, where for some people a certain situation may represent an opportunity, for others it might be a constraint. A common example of opportunities and constraints is usually provided by the local housing market; for instance in a specific location where the market is low, some people might want to move to another neighborhood but since prices are low this might represent an obstacle, while for another person, low prices might trigger him to move.

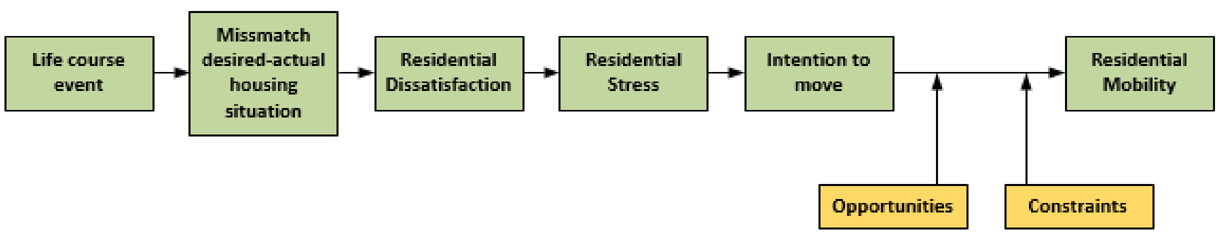


Figure 2. *Residential Mobility Process (Coulter, Ham , & Feijten, 2010)*

In figure 2, the traditional residential mobility process is shown, where it all starts with a specific life stage that generates a mismatch of desired and actual housing situation that causes dissatisfaction and therefore stress which triggers the household's intention to move. Whether this move is done or not will depend on the constraints and opportunities of each specific case.

Above, housing and the process of residential mobility have been addressed, therefore, the factors that influence housing behavior, as well as models that can predict such selections will be part of the discussion in the next section of this paper.

2.3 Housing preference and choice behavior

Preferences and choices are lifetime constants. Every person lives and operates within the framework of choosing from alternatives of life's endeavors in whatever area (Bako Zinas, 2009), in other words, preferences can be seen like choices. Housing preferences and choices represent no exception to this framework. In any preference and choice activity there are underlying motivations that make it possible for an individual to choose from available alternatives within a given product field (Bako Zinas, 2009).

Regarding housing preferences, various factors have been found to have an influence on people's residential choices, however, it has long been a challenge to determine these factors and the degree of their influence (Plagiara, Preston, & Kim, 2005). Housing characteristics such as price and size are thought to influence housing preference and housing choice behavior substantially (Lee & Waddell, 2010; Dieleman, 2001). To a lesser extent, aspects of the residential environment, such as green areas, shopping and parking influence housing choice decisions (Plagiara, Preston, & Kim, 2005; Louviere & Timmermans, 1990). Less important but still influential are social and economic ties and relative location aspects, such as accessibility and travel time to shopping centers, schools and public transportation (Plagiara, Preston, & Kim, 2005; Lee & Waddell, 2010; Louviere & Timmermans, 1990). Additionally, research has shown that many socio-demographic variables influence residential mobility decisions. Factors like age, gender, household income, employment status, education level and household composition were found to predict housing choice behavior (Geist & McManus, 2008; Lee & Waddell, 2010; Timmermans, Borgers, Van Dijk, & Oppew, 1992).

Researchers have not agreed on an exact set of criteria that is able to determine housing behavior of people, however it is clear that such attributes can be classified into two categories: residential environment and demographic characteristics (Campbell, Converse, & Rogers, 1976). People's housing environment refers to the residential environment consisting of the housing unit, the neighborhood and the community in which the residents are located; it includes facilities, infrastructure, services, amenities and the social capital within the neighborhood (Campbell, Converse, & Rogers, 1976). The demographic criteria refers to characteristics of the person or the household itself (Lee & Waddell, 2010).

The issues of housing choice and preference attract interests from researchers in a variety of disciplines. Because of this multidisciplinarity, research into housing preference gives rise to numerous different approaches and models (Jansen, Coolen, & Goetgeluk, 2011). What consumers want can be measured in many different ways. Which particular method is to be chosen can only be answered in the light of the purpose of the measurement (Hooimeijer, 1994). Different methods lead to different outcomes, therefore, the choice for a specific method cannot be based on the methodological superiority of one method over another but should be directed by the type of information in which one is interested (Hooimeijer, 1994). In the following paragraphs, common approaches to determine housing choice will be presented.

The Housing Demand Research Method consist in making relatively simple and straightforward questions about the willingness to move, preferences for housing (environment) characteristics and the current and previous housing situation. Furthermore, socio-demographic and economic variables are collected. Boumeester (2011) says that the goal of this methodology is to obtain accurate insight into the current and future demand for housing in a quantitative and qualitative sense.

Another common approach is the Decision Plan Net. Floor and van Kempen (1997) describe it as the underlying protocol that people use to evaluate alternative houses in terms on the housing attributes that are important to them. The purpose of this method is to present a flow diagram with the underlying decision protocol of people. This diagram is obtained by first recording for each important housing attribute the individual's preferred level and then determining the importance of each preferred housing attribute.

Coolen and Hoekstra (2001) proposed a method called Meaning Structure. The purpose of it is to assess what people's housing preferences are and why they have such preferences. Each housing attribute is assumed to yield consequences, while the importance of consequences is bases on their ability to satisfy people's personally motivating values and goals. Hence, a meaning structure chain relates the preference for a housing attribute to its contribution to the realization of objectives and values.

The Multi Criteria Evaluation method (MCE) or Multi Criteria Decision Analysis (MCDA) targets to value and weight each of all the attributes that are part of a decision process and subsequently, combining the weighted values into an overall utility score where, the alternative with the highest utility represents the optimal choice (Majumder, 2015). This method was originally designed for complex decision making processes.

Conjoint Analysis base its methodology on responses to residential profiles that are complete descriptions of the characteristics of the house and the housing environment (Jansen, Coolen, & Goetgeluk, 2011). This method is especially useful if the researcher is interested in the trade-offs people make between residential attributes. The aim of Conjoint Analysis is to estimate utility functions that can be used to compare residential alternatives in terms of people's preferences.

The research method called Residential Images aims to create a realistic house-hunting process by showing a catalog of available prototypes of existing or newly built housing (Jansen, Coolen, & Goetgeluk, 2011). This method measures the acceptance or rejection degree of new housing at first sight. The aim of this method is to force individuals to trade off their individual wishes taking price and availability into consideration.

The Neoclassic Economic Analysis states that buyers and sellers are able to rank and value the bids and offers for goods on the market (Jansen, Coolen, & Goetgeluk, 2011). The subjective value that households attach to a good gives rise to their bids; the exchange of goods only takes place among buyers who cannot find another seller who asks less and sellers who cannot find another buyer who bids more in a certain period. The optimal choices of sellers and buyers on the housing market can this reveal their preferences for housing quality.

Another commonly used method is the Longitudinal Analysis. In this method the same sample of respondents is followed at different points in time (Jansen, Coolen, & Goetgeluk, 2011). The goal is to examine how characteristics or circumstances at one point in time shape individual outcomes at a later point in time. This technique allows to be performed in a number of ways using various statistical techniques.
In the previous paragraphs different attributes to measure housing preference and choice, as well as several methods proposed by various authors to measure housing preference were presented. Each method presents different scopes and therefore, the selection of a specific method must be based on the type of information in which the researcher is interested to obtain.
In the next section student housing will be addressed.

2.4 Student housing

The topic of housing choice and housing preference continues to be heavily researched, as an area of interest to scholars in various and numerous disciplines (Coolen, 2001). More recently, this interest in housing preferences has shifted towards a rising market which is the student accommodation development.

The traditional student housing market was characterized by shared bedrooms and bathrooms, however, the millennial generation has higher expectations for their student housing (La Roche, Flaningan, & Copeland, 2010). The millennial generation is influencing the market in such a way that accommodation providers are continuing to keep up with the latest design trends; the demands to continually provide enticing personal and social spaces is greater than ever before.

University Business identified 6 trends in student housing: luxury, privacy, privatization, live and learn, safety and security and go green (La Roche, Flaningan, & Copeland, 2010). The luxury trend refers to the availability of amenities that in the past were considered luxuries, such as social areas, lounges, roof terraces, etc. Privacy relates to personal spaces like private bedrooms and bathrooms. The live and learn concept can be understood as proximity to universities as well as to shops and stores. Safety and security also has an important role in the student housing where safer areas are often on higher demand than others. Finally, the go green trend privilege self-sustainable developments.

In USA, Graduate and Professional Student Housing supply has been divided into four different models, where each, is targeted towards a different market (Cheskis, 2012). One model provides inexpensive housing, targeting first year and international students who live alone. The goal is to help them with acclimation to graduate school life, and, in the case of international students, to the country and its culture. In this first model, graduate students might be housed in single rooms with shared floor kitchens. The low cost label means small rooms, basic interior finishes and few building common spaces.

The second model provides housing for students with families, often in outdated apartment buildings. Many universities have a small neighborhood of buildings devoted to this type of housing, thus creating a community for the residents. Communal spaces include laundry rooms and it might include a meeting or recreation room. These type of apartments typically have a large master bedroom and a smaller second unfurnished rooms.

In the third model, the school buys older medium-sized multi-family houses or apartment buildings near to campus to house graduate students. Typically these buildings provide very few common spaces other than a laundry room. The main difference between this model and the first two is that this type of housing provides one stop housing shopping geared towards graduate students, where it is common to review and reserve apartments online before arriving, rent for the academic year instead of calendar year and pay by term using student billing. Even, some schools subsidize the cost of apartment housing, particularly in areas where market rents are steep. Utilities and Internet are included and buildings are services by university's staff.

The fourth model provides new apartment living for all graduate and professional students. The main difference with any other model is that it is a completely new construction specifically designed for students. It may include mixed use occupancy, with first floor retail and residential on top floors. The design contemplates a wide array of common spaces to foster communication between different demographic groups, different intellectual disciplines and between students and faculty. In addition to study spaces, common spaces may include patios, fitness rooms, meeting rooms and even a concierge desk to monitor building security.

The previous housing model classification was based on the American model, which represents a good example of a mature student housing market (Cheskis, 2012) However, in the Netherlands the student housing situation deviates from the American model.

Universities in the Netherlands do not have a big tradition of on-campus accommodation, however this is changing and currently several universities are investing in such type of facilities (Nuffic, 2015). Typically, students in the Netherlands (who do not live with their parents) live either in student houses or student apartments.

In the Netherlands, there is no national student housing database that can provide an accurate number of the total student housing stock or their characteristics. This is partly due to the fact that the ownership of student houses is dispersed. The largest single group of owners are the social housing corporations, which own and manage an estimated of 40% of the total market; the remainder of the stock is owned by private investors who hold a small number of rooms as an investment or for their children to live in while studying. (CBRE, 2015).

To give an estimate for the total of student rooms in the Netherlands, the total number of students living away from home can be used as benchmark. Based on this assumption, the total stock was estimated to be of 400,000 in 2014 (CBRE, 2015)

In the Dutch education system, higher education is divided into WO and HBO, of which WO stands for scientific education or university of science and HBO for higher vocational education, college or university of professional education. In 2016, there were 63,000 new enrolments at research universities for the academic year 2016/2017 which brought the total number of students at this type of university to 249,400. In universities of applied sciences there were 99,700 new enrolments which represents a total of 428,200 students. (Savills World Research , 2017)

With the increasing number of students over the last years, the demands for student accommodation has grown as well. Supply has not kept up with this growth, resulting in a shortage of available rooms. To meet the shortage, the national government together with municipalities, housing corporations, investors and universities have signed an agreement to build new student housing (Landelijk Actieplan Studentenhuisvesting 2011-2016), however, the majority of student cities are still dealing with a substantial student room's scarcity (CBRE, 2015). In addition to this shortage, the long-term demand pressure on the market has obliged students to accept lower quality rooms and has led to underinvestment by landlords. At the same time, demand for high quality rooms has risen; as a result, there is not only room for additional student housing supply, but also for improvement in the quality of the current stock (Savills World Research, 2016)

Purpose Built Student Accommodation (PBSA) are new developments that are designed with only one objective: to fulfill the requirements and necessities of students. In general terms, these constructions offer enclosed rooms with private shower and bathroom, open plan living spaces, social areas within the building, proximity to a university and high accessibility (Savills World Research, 2016). PBSA's are the market response to the strong student housing demand and in the Netherlands, they represent one of the most popular real estate investments in the last years

In figure 3 it is shown all the deliveries of PBSA's from 2015 projected to 2018.

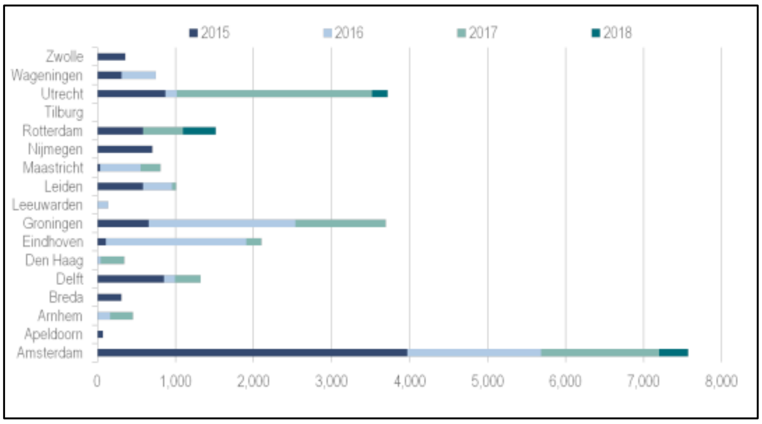


Figure 3. *Deliveries PBSA in the Netherlands 2015-2018 (Savills World Research, 2016)*

From figure 3 it is possible to observe which cities have the higher student housing demand and how such demand is planned to be satisfied in the upcoming years. It is clear that Amsterdam, Delft, Eindhoven, Groningen, Rotterdam and Utrecht have the highest student room's demand but it is also interesting to note that there are some smaller cities that also present increasing student housing demand.

2.5 Conclusions

In the previous paragraphs several concepts were discussed. Housing was defined as a specific product with unique functions (shelter, center of domestic activities, etc.) as well as residential mobility, its triggering factors and it's over all process.

Also in this chapter a review of the factors that have influence over people's housing preferences was made. It was stated that there is not a specific set of criteria that can determine such preference because each scenario is different to any other, however it was noted that these attributes can be classified into two groups: residential environment and demographic characteristics. The first refers to all that surroundings and the characteristics of the house itself; the second refers to the characteristics of the person or household. Regarding the different methodologies that exist to evaluate housing preference, nine commonly used were discussed. It was stated that there is no better method, but instead, each method is used depending on the required results.

In the last part of this chapter student housing was assessed. First a general overview of the student housing market was made as well as a description of how the student housing model in a mature market is arranged. Then the Dutch student housing market was discussed. It is clear that supply is lower than demand in most regions of the Netherlands and PBSA's are the trend in student housing, however it is important to note that due to the large number of recent student room's and future deliveries, investors have to be more selective regarding the locations. Hence the importance of this research. By identifying the locations that better satisfy student's preferences it will be possible to further develop real estate investment portfolios as well as allowing municipalities and universities to increase their number of students.

In the following chapter a review about the selected method to assess student's location preferences as well as all its implications for this research will be shown.

CHAPTER 3

Multi Criteria Evaluation Analysis

3.1 Introduction

In the previous chapter nine commonly used methods to evaluate housing preference were discussed. It was stated that none of them could be categorized as better than any other due to the different objectives that each method pursues. Recalling this research's question "what location factors are important in student's preference regarding PBSA, and how these factors can be included in a land suitability analysis?" it is clear that the methodology that better suits this research's objectives is the MCE method because it is able to evaluate complex decision problems with multiple variables.

This chapter will focus on the MCE methods as well as its implications for this research. In the first part a general overview of the MCE methodology is explained, also several approaches within this method are assessed.

Afterwards, the focus will be on the LSP method and its implications and requirements. To finalize this chapter, a revision of the typically attributes used in suitability analysis will be made

3.2 Multi criteria evaluation methods

Decision making is regarded as the cognitive process that results in the selection of a belief or a course of action among several alternatives. Every decision making process has as outcome a final choice. This decision making process can be very simple if the number of variables is low, however, when the process involves several criteria the entire procedure becomes more difficult to assess.

Multi criteria decision making (MCDM) is considered a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in the decision making environment. In our daily lives we unconsciously weight multiple criteria and often we find ourselves satisfied with the consequences of such decisions. However, when stakes are high, it is imperative to properly structure the decision problem and explicitly evaluate multiple criteria and several solutions; this approach leads to more informed and better decisions.

Multi-dimensional decision and evaluation models provide tools for analyzing complex trade-offs between choice alternatives with different environmental and socioeconomic impacts. The formal mathematical framework used to describe multi-dimensional decision making is based on multi-objective optimization theory in which both conflicting and complementary objectives are described as a decision problem with multiple objectives (Carver, 1991). The basic aim of MCE analysis techniques is to investigate a number of choice possibilities in the light of multiple criteria conflicting objectives, by doing this it is possible to generate compromise alternatives and rankings of alternatives according to their attractiveness (Voogd, 1983).

In the field of land use and space analysis, multi criteria decision problems are not rare, decision makers are often faced with high intricacy dilemmas that require more complex tools to solve. Geographical Information Systems (GIS) provide the decision maker with a powerful set of tools for the manipulation and analysis of spatial information (Carver, 1991). GIS provide means that, when combined with MCE methods, can be used to solve a multitude of problems involving spatial data. Geographic information systems have been used for the site selection of areas, such as: service facilities, recreational activities, retail outlets, hazardous waste disposals sites and critical areas for specific resource management and control practices (Jancowski, 1995). However, the utility of GIS functionality in the management of such areas has been limited by the restrictions inherent in overlaying of digital information maps (Janssen & Rietved, 1990). The integration of analytic techniques designed to work with MCE problems within GIS could give more functionality to the user. GIS are very useful for storing, processing and manipulating spatial databases; consequently the integration of MCE within a GIS context can help users to improve decision making processes (Pereira & Duckstein, 1993)

Spatial decision problems typically involve a large set of feasible alternatives and several evaluation criteria, therefore many decision makers give rise to the GIS-based multi criteria decision analysis. On one hand GIS is recognized as a decision support system that involves the integration of spatially referenced data in a problem solving environment; on the other hand, MCE provides a rich collection of techniques and procedures for structuring decision problems and designing, evaluating and prioritizing alternative decisions (Malczewski, GIS-based multicriteria decision analysis: a survey of the literature, 2006)

Research has shown several authors applying different MCE methods to complex spatial decision problems. Some of the commonly used methods used are: Simple Additive Weighting (SAW) (Azar, 2000; Kaliszewski & Podkopaev, 2016; Giupponi & Gain, 2016), Multi Attribute Value and Utility Theory (MAUT) (Dujmović, De Tre, & Dragićević, Comparison of Multicriteria Methods for Landuse Suitability Assessment, 2009; Kiker, Bridges, Varghese, Seager, & Linkov, 2015; Veldhuisen & Timmermans, 1984), Ordered Weight Average (OWA) (Yager, 1988; Malczewski, Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis, 2006; Zeng, Balezentis , & Zhang, 2012), Outranking Methods (Roy, 1991; Kangas, Kangas , & Pykäläinen, 2001; Rogers & Bruen, 1998) and more recently Logic Scoring of Preference (LSP) (Dujmović & Fang, Reliability of LSP Criteria, 2004; Hatch , Dragićević , & Dujmović, 2014; De Tre, Bronselaer, Matthe, & Dujmovic, 2011)

SAW is probably the best known and widely used method for multiple attribute decision making. It was first utilized by Churchman and Ackoff in 1954 while coping with a portfolio selection problem. This method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of the attribute with weights of relative importance directly assigned by each decision maker; after this a sum of all the products for all criteria is made. The main advantage of this method is that it propose a proportional linear transformation of the raw data (Afshari, Mojahed, & Yusuff, 2010). The main disadvantage of the SAW method is that it does not consider the different preferential levels and preferential ranks for each decision maker's assessment of alternatives in a decision group (Abdullah & Adawiyah, 2014)

MAUT is a method used to support a decision maker when it has to choose from a limited number of available alternatives. The overall evaluation of an alternative is defined as a weighted addition of its values with respect to its relevant attributes; this method requires the decision maker to evaluate the alternatives on each value dimension separately. Values and weights are then combined and aggregated by means of a formal model that generates an overall evaluation of each alternative (von Winterfeldt & Edwards, 1986). Several authors point some disadvantages of this method: it supposes that human values may only influence consumer choices by affecting what product attributes consumers prefer and that is the calculated evaluation of product attributes that in turn determines product choice, however, consumers also make emotionally, intuitive and holistic judgments (Allen, 2002); the method assumes that the importance of the attribute is independent of the level of the attribute, which may not hold as the importance of the attributes may be dependent upon the range of the scale over which the value function is defined (Jansen, Coolen, & Goetgeluk, 2011); respondents may not be able to provide evaluations for a distinct attribute level without taking related attributes into account (Jansen, Coolen, & Goetgeluk, 2011); the MAUT method does not allow testing of the appropriateness of the chosen preference function to combine the single- attribute utilities into an overall utility (Veldhuisen & Timmermans, 1984)

OWA is a family of multi criteria combination procedures (Yager, 1988). It involves two sets of weights: the weights of relative criterion importance and the order (or OWA) weights. By specifying an appropriate set of the OWA weights, one can generate a wide range of different land-use suitability maps (Malczewski, 2006). The OWA operator is able to provide a parameterized family of aggregation operators, which typically includes maximum, minimum and average (Zeng, Balezentis , & Zhang, 2012), hence its application in several fields. The main advantage of the OWA is the concept of orness (fuzzy membership) and the definition of an orness measure that can establish how “or like” a certain operator is based on the values of its weighting function. One disadvantage of this method is its inability to model certain scenarios where symmetric linguistic variables are not the best fit for the case. From this limitation many unbalanced linguistics aggregators have been proposed making the method more robust and complex.

The OM method builds a preference relation, typically called outranking relation, among alternatives evaluated on several attributes. The outranking relation is built through a series of pairwise comparisons of the alternatives. This method enable the utilization of incomplete value information and, for example, judgments on ordinal measurement scale (Rogers & Bruen, 1998). The method provides the (partial) preference ranking of the alternatives, not a cardinal measure of the preference relations. The principle of the OM’s rests on a voting analogy and can be used without having recourse to a subtle analysis of trade-offs between attributes. An important advantage of OM is the ability to deal with ordinal and more or less descriptive information on the alternative plans to be evaluated; the uncertainty concerning the values of the criterion variables can be taken into account using fuzzy relations determined by indifference and preference. However, the difficult interpretation of the results is the main disadvantage of the OM (Kangas, Kangas , & Pykäläinen, 2001), as well as its lack of axiomatic foundations.

The LSP method analyzes complex trade-offs between choice alternatives, based on precise modeling of human evaluation reasoning (Dujmović & Fang, Reliability of LSP Criteria, 2004), this methodology provides the flexibility, precision and justifiability of evaluation criteria derived from the structural and logic consistency with observable properties of evaluation reasoning. The end result of the LSP method is a suitability map, in which, criterion functions can use any number of input attributes and generate an overall suitability score which is defined as a degree of truth of the statement that all requirements are satisfied (Hatch , Dragićević , & Dujmović, 2014). The main advantage of LSP is that it is able to compute an infinite number of inputs without losing significance as well as taking into consideration objective and subjective factors into the decision making process.

3.2.1 Pairwise comparison

All of the previous MCE methods represent different approaches to solve complex spatial decision problems. However, these methods are worthless if they are not fed with attribute weights. An attribute weight represent the importance of each attribute in the overall decision making process. Pairwise comparison is a methodology designed to make decision makers indicate how much more important, or how much more desirable, or how much better qualified and item is compared to a similar one (Dijkstra, 2010)

Saaty is an outspoken proponent of this approach. His method, the Analytical Hierarchy Process (AHP) considers a set of evaluation criteria and a set of alternative option among which the best decisions is to be made. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria, where verbal intensity of the comparison is translated into numbers, using scales that appear to work well in practice: 1 for equal importance, 3 for moderate importance, 5 for strong, 7 for very strong and 9 for extreme importance, integers in between for refinements and reciprocals for inverse judgements (Dijkstra, 2010); the higher the score, the better performance of the option with respect to the considered criterion. Finally, this method combines the criteria weights and the option scores, determining a global score for each option, and a consequent ranking. The global score for a given option is a weighted sum of the scores it obtained with respect to all the criteria (Saaty T. L., 1980).

The AHP method presents considerable advantages such as its ability to rank choices in the order of their effectiveness in meeting conflicting objectives, as well as its capacity to detect inconsistent judgments. However, the main disadvantage of this method is that it only works because the comparison matrices are all of the same mathematical form (reciprocal matrices). It is important to note that the AHP is a method proposed to evaluate human choice, therefore certain inconsistency can be expected. For instance, if B > A and A > C, logically B > C, this is what is called transitive property. Consistency is closely related to the transitive property, however, in human decision not always all the results are consistent. Saaty proved that for consistent reciprocal matrix, the largest Eigen value is equal to the size of comparison matrix, or max $\lambda = n$; then, he gave a measure of consistency called Consistency Index (CI) as a degree of consistency using the formula CI= λmax-n/n-1. To be able to use the CI, Saaty proposed to compare this index with the appropriate consistency index, which is called Random consistency Index (RI). The RI are values generated from reciprocal matrices using scales 1/9, 1/8, etc. and from them, the RI is compared to see if it is about 10% or less. Saaty also proposed a calculation called Consistency Ratio (CR), which is a comparison between CI and RI (CR=CI/RI). If CR is smaller or equal to 10%, the inconsistency is acceptable.

In the previous paragraphs an overview of the commonly used MCE methods was discussed, as well as a methodology to determine attribute weights which are used by these MCE methods. From all the typically used methods, LSP was selected to perform a suitability analysis for student location attributes. This choice was made based on the advantages that such method propose over other MCE methods. In the following section the LSP method will be assessed as well as its implications and requirements.

3.3 Logic scoring of preferences

LSP is a multi-criteria evaluation method, first proposed by Jozo J. Dujmovic, that resembles human evaluation reasoning (Dujmović & Fang, Reliability of LSP Criteria, 2004). The method provides an evaluation criteria derived from the structural and logic consistency. The structure of each LSP criterion function is based on a set of attributes, the corresponding attribute criteria and a soft computing logic aggregation of attribute suitability scores. One of the bestselling points of the LSP methodology is its offer of specific type of elementary attribute criteria, as well as the aggregation operators of attribute suitability scores which includes all of the ones that are observable in human reasoning: hard and soft partial conjunction, hard and soft partial disjunction, pure conjunction and disjunction, conjunctive/disjunctive neutrality, asymmetric aggregators and complex canonical aggregation structures. (De Tre, Bronselaer, Matthe, & Dujmovic, 2011). It also provides a separate selection of formal logic parameters of andness and orness and semantic parameters of relative importance of attributes in aggregation structures.

LSP follows an aggregation structure where data inputs are represented on a standardized scale and organized into relevant attributes; inputs are grouped categorically and arranged on a LSP attribute tree; afterwards they are combined through the use of different LSP aggregators which represent a spectrum of conditions ranging from simultaneity to replaceability (Dujmovic , De Tre , & van de Weghe, 2010). The method can be implemented in 3 stages: development of an attribute tree, definition of attribute criteria and the development of the aggregation structure.

3.3.1 LSP attribute tree

The first step of the LSP methodology consists in the creation of a list of suitability attributes, then a decomposition structure is generated. This structure organizes the decision problem using a hierarchical structure of attributes; from the breakdown of the overall suitability it yields a distribution tree where elementary attributes are the leaves of it. The input attributes are separately evaluated and corresponding suitability degrees are then combined together using the LSP aggregators. A very important factor of the LSP attribute tree is that some of its attributes can be denoted as mandatory (satisfaction is required) while some others are optional (satisfaction is desired). In figure 4 it is possible to observe an example of such arrangement, where mandatory attributes are represented with (+) and non-mandatory attributes are represented with (-)

1 **Terrain and environment** (+)
    11 Terrain properties (+)
        111 Slope (+)
        112 Altitude (+)
        113 Orientation of terrain (-)
    12 Environment properties (-)
        121 Proximity of forests or major green areas (-)
        122 Proximity of a lake/river (-)
2 **Location and accessibility** (+)
    21 Ground transportation (+)
        211 Proximity of an interstate highway (+)
        212 Proximity of a regional highway (+)
        213 Proximity of an intercity railroad station
    22 Proximity of an international airport (-)
3 **Population and employment opportunities** (+)
    31 Density of population (+)
    32 Proximity to employment opportunities (+)

Figure 4. *Mandatory (+) and optional (-) attributes (Dujmovic , De Tre , & van de Weghe, 2010)*

3.3.2 Attribute criteria

The second step to implement the LSP method is to specify individual requirements for all attributes. The attribute criteria reflects decision maker's requirements that the input has to satisfy; these requirements are expressed as functions that show the level of satisfaction (y axis) with each value of the attributes.

The level of satisfaction is also known as elementary preference, and it belongs to the interval [0,1], where elementary preference 0 reflects null satisfaction of the input and 1 shows full compliance with the requirement, elementary preferences between 0 and 1 represent partial fulfillment of the requisite (Montgomery & Dragicévic, 2016). In figure 5 it is possible to observe an example of attribute criteria functions.

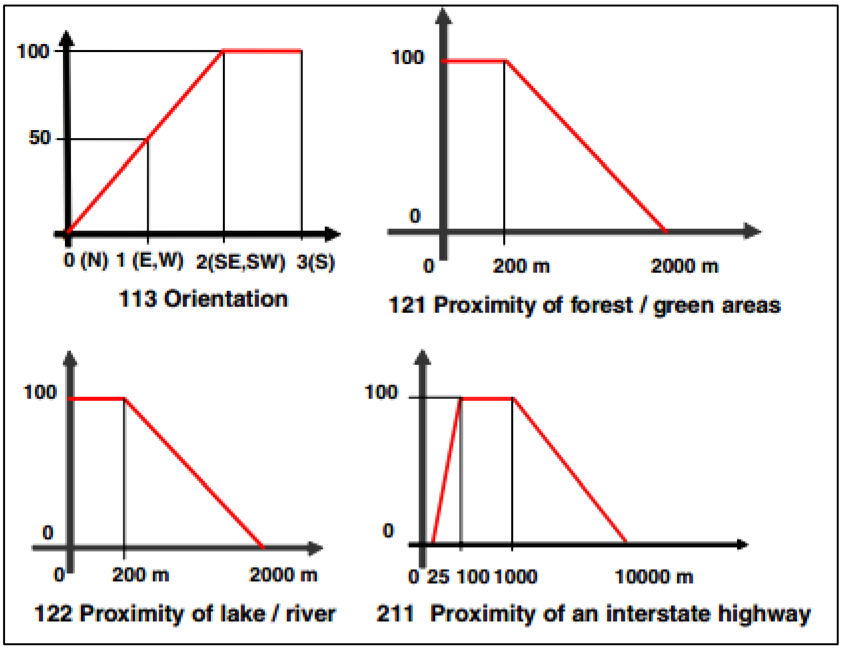


Figure 5. *Attribute criteria functions. (Dujmovic , De Tre , & van de Weghe, 2010)*

The attribute criteria shown in figure 5 represent the suitability function that the LSP model will use to evaluate each location. For instance, if proximity of forest or green area is evaluated, any location that is within 0-200m away from a forest or a green area will yield a suitability score, for this attribute, of 100. However, from 201-2000m the suitability score will be reduced in function of the slope of the attribute criteria plot. Any location that is more than 2000m away from a forest or green are will be considered to be unsuitable (0).

3.3.3 LSP AGGREGATION STRUCTURE

The third step in the design of LSP suitability maps is the organization of the preference aggregation structure, which will aggregate all the elementary preferences and will result in the overall suitability. Each aggregator computes the usefulness of a group as a function of the usefulness of group components. Each aggregator function must be able to express logic and semantic relationships between components in a justifiable way that is derived from knowledge of a domain expert (Dujmovic , De Tre , & van de Weghe, 2010). In table 1 it is possible to observe the classification of the fundamental Continuous Preference Logic (CPL) aggregators

<table>
<tr><td rowspan="12">Aggregation operators in Continuous Preference Logic (CPL)</td><td rowspan="7">Generalized Conjunction/ Disjunction (GCD) – the basic CPL aggregator</td><td colspan="2">Full disjunction (D)</td></tr>
<tr><td rowspan="2">Partial disjunction (PD)</td><td>Hard partial disjunction (HPD)</td></tr>
<tr><td>Soft partial disjunction (SPD)</td></tr>
<tr><td>Neutral aggregator</td><td>Arithmetic mean (A)</td></tr>
<tr><td rowspan="2">Partial conjunction (PC)</td><td>Soft partial conjunction (SPC)</td></tr>
<tr><td>Hard partial conjunction (HPC)</td></tr>
<tr><td colspan="2">Full conjunction (C)</td></tr>
<tr><td rowspan="5">Compound aggregators</td><td rowspan="2">Simple partial absorption</td><td>Disjunctive partial absorption (DPA)</td></tr>
<tr><td>Conjunctive partial absorption (CPA)</td></tr>
<tr><td rowspan="2">Nested partial absorption</td><td>Sufficient/Desired/Optional (SDO)</td></tr>
<tr><td>Mandatory/Desired/Optional (MDO)</td></tr>
<tr><td colspan="2">Partial equivalence, partial implication, etc.</td></tr>
</table>

Table 1. *Aggregation Operators in CPL (Dujmovic , De Tre , & van de Weghe, 2010)*

Partial Conjunction and partial disjunction are two special cases of General Conjunction/Disjunction (GCD). Partial Conjunction is a model of simultaneity while partial disjunction represents replaceability. The degree of similarity between any form of GCD and the full conjunction is called “andness” and the degree of similarity between any form of GCD and full disjunction is called “orness” (Montgomery & Dragicévic, 2016)

The GCD functions range from full disjunction (D) to full conjunction (C). These two operators represent the limits of GCD where full disjunction presents a high level of “orness” (1) and a low level of andness (0); full conjunction represents a low level of “orness” (0) and a high level of “andness” (1). The levels in between D and C indicate different values of “orness” and “andness”. In total LSP uses a system of 17 discrete levels, where each represent a different degree of andness and orness. Such levels and its symbols are shown in Table 2.

Operator	Symbol	Orness ω	Andness α	Exponent r
Full disjunction (**or**)	**D**	1.000	0	$+\infty$
Partial Disjunction (**orand** function)	**D++**	0.9375	0.0625	20.63
	D+	0.8750	0.1250	9.521
	D+-	0.8125	0.1875	5.802
	DA	0.7500	0.2500	3.929
	D-+	0.6875	0.3125	2.792
	D-	0.6250	0.3750	2.018
	D--	0. 5625	0.4375	1.449
Neutrality	**A**	0.5000	0.5000	1
Partial Conjunction (**andor** function)	**C--**	0. 4375	0.5625	0.619
	C-	0.3750	0.6250	0.261
	C-+	0.3125	0.6875	-0.148
	CA	0.2500	0.7500	-0.72
	C+-	0.1875	0.8125	-1.655
	C+	0.1250	0.8750	-3.510
	C++	0.0625	0.9375	-9.06
Full conjunction (**and**)	**C**	0	1.000	$-\infty$

Table 2. *SPC aggregators (C--, C-) and HPC (C-+, CA, C+-, C+, C++) (Dujmovic , De Tre , & van de Weghe, 2010)*

To implement the GCD functions into the aggregation structure, Dujmovic proposed several operators. Each of them represent a different level of “orness” and “andness” as well as a different exponent (r) value. The exponent r indicates the adjustable degrees of andness/orness of the aggregator. Full conjunction (C) and Hard Partial Conjunction (HPC) operators are models of high simultaneity and mandatory requirements, which means that all inputs must be satisfied (at least), if any input in an aggregated group of preferences is 0, the output will turn out 0 (Dujmovic , De Tre , & van de Weghe, 2010). Soft Partial Conjunction (SPC) operators are a model of simultaneity but its simultaneity level is lower than HPC. The neutrality aggregator (A) presents a perfect balance between simultaneity and replaceability and Disjunction (D), Hard Partial Disjunction (HPD) and Soft Partial Disjunction (SPD) are models of replaceability symmetrical to C, HPC, and SPC. It is the decision maker’s responsibility to use the appropriate LSP operators.

Once the aggregator operators are selected, the next step to create the LSP aggregation structure is to define the aggregation operations of the structure. When combining two or more mandatory inputs or two or more optional inputs, each of the LSP aggregators aggregate the inputs using the weighted power mean function (WPM)

$$GCD(X_1, \dots, X_n) = [W_1 X_1^r + \cdots + W_n X_n^r]^{1/r}$$

Where:
GCD= General Conjunction Disjunction
X= Suitability score (from attribute criteria functions)
W= Attribute weight
r= Adjustable degree of andness/orness

When combining mandatory with optional inputs the Conjunctive Partial Absorption (CPA) function must be used

$$CPA(X,Y) = [(1 - W_2)[W_1 X^{r_1} + (1 - W_1) Y^{r_1}]^{r_2/r_1} + W_2 X^{r_2}]^{1/r_2}$$

Where:
CPA= Conjunctive Partial Absorption
X= Suitability score input 1(from attribute criteria functions)
Y= Suitability score input 2 (from attribute criteria functions)
W1= Attribute weight of input 1
W2= Attribute weight of input 2
r1= Adjustable degree of andness/orness of input 1
r2= Adjustable degree of andness/orness of input 2

The CPA aggregator scheme operates so that the optional input penalizes or rewards the overall output from the combination of mandatory and optional inputs. (Dujmovic J. , 1979)

Another important part of the aggregation structure is the definition of the attribute weights, Dujmovic says that there are 3 ways of determining such values: using analytical hierarchy process (AHP), neural networks or using the perceptions of experts (decision maker, stakeholders, etc.). Once all the previous steps are completed, the aggregation structure is ready to be computed into any computational package. In figure 6 an LSP aggregation structure can be observed.

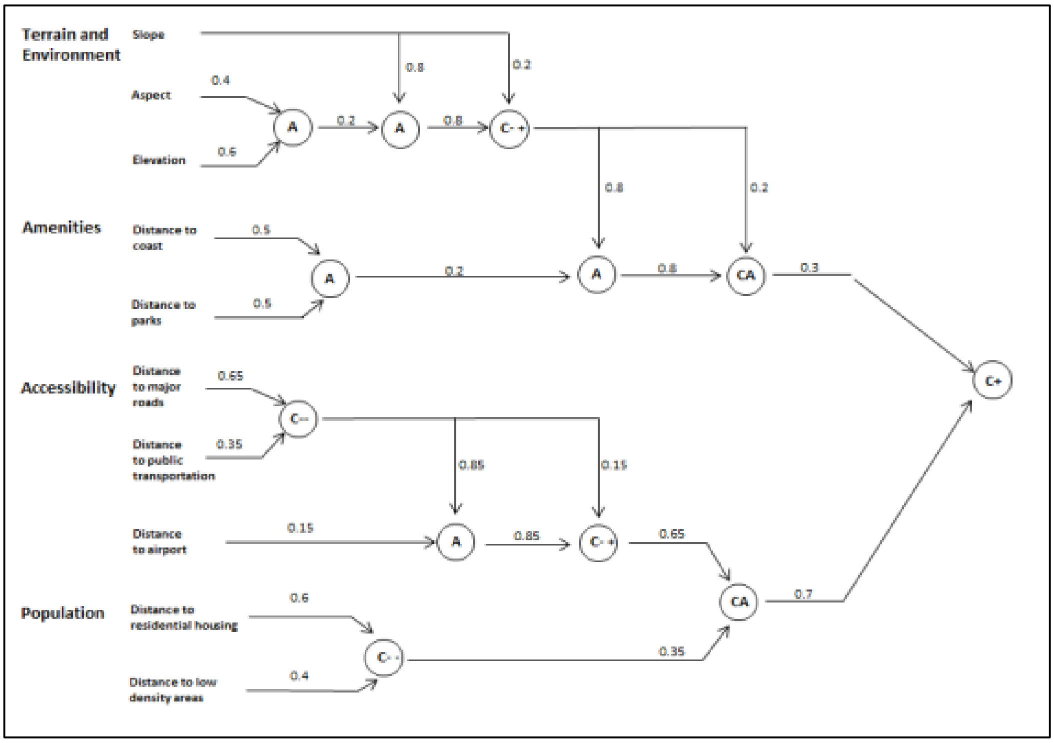


Figure 6. *Aggregation Structure (Hatch , Dragićević , & Dujmović, 2014)*

The Aggregation Structure shown in figure 6 is an example of how the LSP method analyzes suitability for a certain location. In this specific case four branches of attributes are taken into account: terrain and environment, amenities, accessibility and population. Each branch is subdivided into several attributes. Taking the Accessibility branch as an example, it is subdivided into three attributes: distance to major roads, distance to public transportation and distance to airport. To obtain an accessibility suitability score these 3 attributes must be aggregated, in order to do so, distance to major roads and distance to public transportation are added using the C-- operator. These two attributes are added first because they both are considered mandatory. Afterwards, distance to airport is added, using the CPA function (aggregate mandatory with non-mandatory inputs), therefore operators A and C-+ are chosen. Once all these three attributes are aggregated an accessibility suitability score is available. To obtain the overall suitability score terrain & environment and amenities suitability must be aggregated and then population suitability must be obtained and aggregated to the accessibility score. Then these must be added giving as a result the overall suitability.

The use of step-wise logic aggregation structure that allows for flexibility through its use of continuous logic represented in terms of simultaneity and replaceability, and the ability to include a large number of inputs without loss of significance for any individual attribute are the features that differentiate the LSP method from any other MCE. However, the biggest difficulty that LSP deals with is the complexity of the model itself which asks for a deep understanding of soft computing concepts.

3.4 Suitability analysis attributes

In the previous section of this chapter the LSP method was explained. From the creation of an attribute tree and attribute criteria functions to the design of an aggregation structure that is used to calculate the overall suitability score of a certain location. In the following paragraphs, a revision of the commonly used suitability attributes in different suitability analysis will be presented.

Hatch, et. all (2014) used the LSP method for the land suitability analysis applied to real geospatial datasets for new urban residential developments in the Metro Vancouver Region in Canada. In this study the LSP method was used to determine spatially optimal locations for urban residential growth across the regional district of Metro Vancouver. The input criteria consisted of selected factors and data that influence residential growth. In this specific exercise, 19 different elementary criteria divided into 4 attribute groups were considered to develop three suitability maps. Terrain and Environment was one of the attribute groups, it included slope, aspect and elevation attributes. Amenities is other attribute group, it included distance to beach, distance to coast, distance to parks, distance to shopping, distance to care facilities and distance to schools. The third attribute group was accessibility, distance to major roads, distance to bus lines, distance to light rail, distance to airport and amount of sustainable transport are criteria that were included in this group. Finally, the fourth group was population and it included distance residential housing, distance to low density areas, distance to family areas, population growth and median income.

Montgomery, et all (2016) used the LSP method, using data from Boulder County, Colorado, USA, to convert agricultural land use for urban development while maintaining enough agricultural land use to support, local, statewide and nationwide agricultural production. In total, 15 elementary criteria, divided into 4 categories, were considered to develop the suitability analysis. Terrain: slope, elevation and aspect. Amenities: distance to surface water, distance to parks and open space, distance to residential housing and distance to agriculture. Population: price of housing, household income, renting and vacancy. Accessibility: distance to major roads, distance to employment, population density and distance to existing urban land use.

Passuello, et all (2012) implemented the LSP method to define the best agricultural areas for sewage sludge amendment in Catalonia, Spain. In total 12 different criteria were occupied: distance to urban areas, crop type, temperatures, rainfall, texture, pH, metals, carbonates, organic matter, slope, ground water and hydrology were the inputs used in this exercise.

Minardi (2012) used the LSP method to analyze suitability areas for urban development in Bowen Island, Canada. Three domain categories were assigned: site, transportation and amenities. The attributes slope and aspect were grouped under site, ferry terminal access and road access were grouped under transportation and coast access and park access were assigned at amenities.

Dujmovic (2010) developed a suitability map using the LSP method to evaluate urban expansion. On his research attributes were classified in three main branches: Terrain and Environment, Location and Accessibility and Population and Employment Opportunities.

Slope, altitude, orientation of the terrain, proximity of forest and proximity of lake/river were grouped into the terrain and environment category. Proximity to interstate highway, proximity to regional highway, proximity to railway and proximity to airport were grouped into location and accessibility criteria. Density of population and proximity to employment opportunities are part of the population and employment opportunities branch.

An important note of all the previous studies is that none of the authors specifies with clarity the logic behind their attribute selection neither where the elementary attribute criteria was obtained from. Most of the found research base their suitability analysis on assumptions of elementary attribute criteria. Dujmovic (2004) says that attribute criteria as well as attribute selection can be assumed based on the decision maker's experience, opinion of experts or it can be obtained from the results of a survey, however, Dujmovic warns that, in order to feed the model with information obtained from a survey, especial attention to the robustness of such survey has to be taken to avoid bias.

3.5 Conclusions

Chapter 3 was divided in three sections. In the first one Multi Criteria Evaluation (MCE) methods were discussed. It was stated that such type of decision making approaches are useful when complex spatial decisions had to be taken as well as a short revision of the literature available of such methods was addressed. From this literature review the Logic Scoring of Preferences approach was selected to answer this research's main question.

Then, a full revision of the LSP method was presented. The concepts of attribute tree, attribute criteria and aggregation structure were explained, as well as a full explanation of how a suitability maps is obtained using the LSP approach.

In the last section, a literature review of LSP suitability maps was presented. It was shown the different attributes that several authors used in their research and how, such attributes, were selected to be part of the analysis.

In following chapter, a detailed explanation of this research approach will be presented.

CHAPTER 4

Research Design and Approach

4.1 Introduction

The scope of this study is the student housing location preferences. This research focuses on the definition of compulsory and desirable location attributes in PBSA's as well as a methodology to pinpoint the best areas to construct such developments, answering "What location factors are important in student's preference regarding PBSA, and how these factors can be included in a land suitability analysis?" No research has yet determined the importance of location attributes in the housing decision process of students, rather, most of previous work focuses on building attributes, such as footprint, amenities, etc.

The methodology followed in this investigation is aligned with the research's main questions and sub-questions, therefore the followed approach can be broken down into two parts. In the very first section, the questions "what are the location attributes that student's care about?" and "what is the level of importance of such location attributes?" are tackled. The second part of this study relates to the third and fourth sub-questions "what method that includes all of the student's location preferences as well as its importance levels, should be used to develop a land suitability analysis?" and "How to implement such method". In the following sections of this paper a more detailed explanation of the methodology will be discussed.

4.2 Survey design

In order to understand what location attributes are important to students a survey was prepared, however, an essential step of designing a survey is to have a clear idea of who the target audience is. For this survey, the main goal was to better understand the location attributes that matter to students as well as its level of importance, hence one first step towards audience characterization relates to the definition of the student group. PBSA's are developments designed for a very specific target group: bachelors, masters and, in some cases, Ph. D. students, therefore the survey was targeted towards this niche. Another consideration of the survey was the respondent's place of living; the scope of this research had the limitation of being a study for the Netherlands only, thus, the survey was designed for students living in the Netherlands. Other characteristics such as gender, age and nationality were also required in the survey, although, these were not considered for the audience targeting process because the aim of the research was not to look for specific preferences of a specific age, nationality or age group; instead students as a whole group was approached.

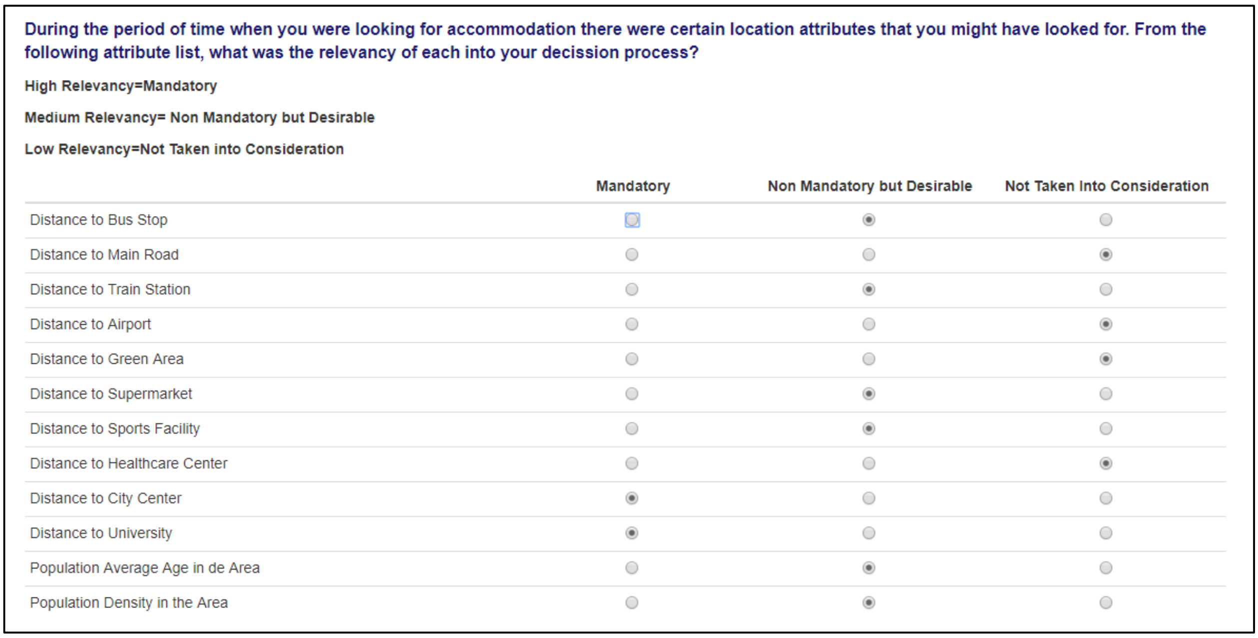
Once the target audience was specifically delimited, the next step followed to create this research's survey was to select the attributes that had to be evaluated. Since the main objective of this work relates to location attributes, a revision of other author's research was made to investigate what categories were used and under what circumstances. Some researchers used the LSP method to convert agricultural areas into other type of land use (Passuello, Cadiach, Perez, & Schuhmacher, 2012; Montgomery & Dragicévic, 2016) while other's main objective was related to urban development or redevelopment purposes (Hatch , Dragićević , & Dujmović, 2014; Dujmovic , De Tre , & van de Weghe, 2010; Minardi, 2012). Because of the nature of this report, authors that addressed urban development issues are of higher interest. In the research performed by these authors, four criteria categories are commonly found (in some cases are combined): terrain, accessibility, amenities and population. In the Terrain branch attributes like slope, aspect, elevation and orientation could be found. In Accessibility distance to main roads, bus stops, train station, airport and ferry were considered. In Amenities distance to beach, coast, parks, shopping areas, health care, schools, forest and lakes were taken into consideration. In the Population criteria, attributes like distance to residential housing, family areas, population density, median income, population growth and employment could be found.

For this research's survey, a selection from the previous criteria was made. Three categories were selected: Accessibility, Amenities and Population. The Terrain category was not chosen because such characteristics are dependent upon the construction process rather than the student's preferences and by adding them the complexity of the model would be higher. However, it must be noted that such criteria is important if the decision maker is looking for specific environment characteristics. For instance, if a project is deemed to be built on a location with certain slope and certain orientation, it would be important to add these constraints into the suitability analysis.

Regarding attribute criteria, for the Accessibility branch four attributes were chosen: distance to bus stops, main roads, train stations and airport. Such attributes were selected because it reflects the majority of the transport means used in the Netherlands. Trams and ferries were not considered because they are not available in the entire country. For the Amenities attributes, six were considered: distance to green areas, supermarkets, sport facilities, health care centers, city center and universities. Such selection was based on the literature regarding student housing and PBSA in which it is stated student preference over certain amenities (La Roche, Flaningan, & Copeland, 2010). Finally, the Population criterion takes into account two attributes: population average age and density. Such attributes were selected because they reflect general characteristics of the social environment and they have been used by other authors in urban development analysis (Hatch , Dragićević , & Dujmović, 2014; Dujmovic , De Tre , & van de Weghe, 2010).

Once the attribute and criteria were specified, the next steps of the survey design had to be conceived together with the MCE method chosen to make a suitability analysis. Depending on what MCE method was selected, was the type of questions that had to be incorporated into the survey. In this research, the MCE methodology chosen was Logic Scoring of Preference (LSP) because of its ability to mimic the human way of making decisions which incorporate objective and subjective factors without losing attribute significance. Also, this method has the capacity to answer this research's main questions and sub-questions.

The second sub-question of this research was related to the level of importance of the location attributes. According to the LSP methodology, the criteria previously defined must be classified into mandatory and non-mandatory but desirable attributes, which tackles the second sub-question, therefore in the first section of the questionnaire it was asked to respondents to arrange the attributes list into three categories: mandatory, non-mandatory but desirable and not taken into consideration. The last level deviates from the typical LSP approach (2 categories) but it was implemented to measure the relevancy of the attribute into the student's decision, therefore validating the importance of the selected attributes, which directly tackles the first sub-question of this research "what are the location attributes that student's care about?" In figure 7 such task is depicted.


During the period of time when you were looking for accommodation there were certain location attributes that you might have looked for. From the following attribute list, what was the relevancy of each into your decission process?

High Relevancy=Mandatory

Medium Relevancy= Non Mandatory but Desirable

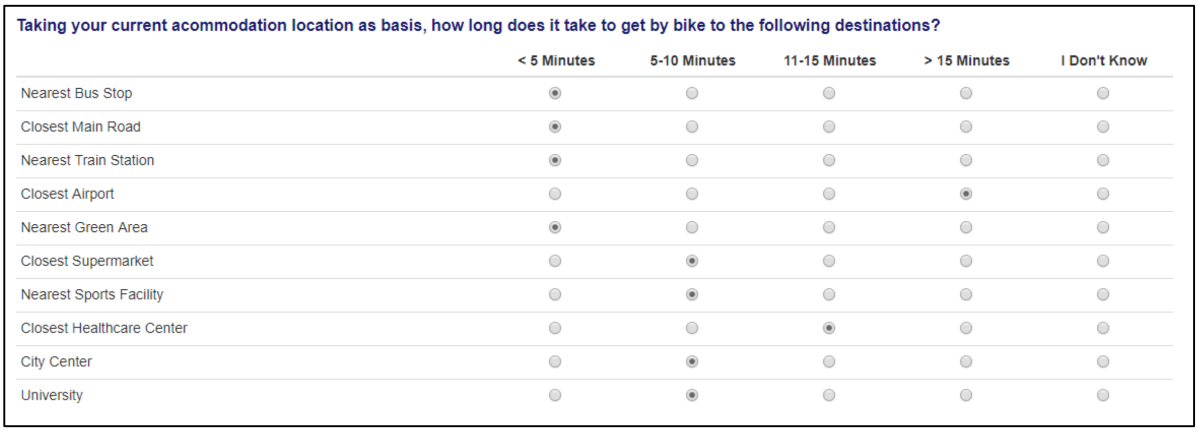
Low Relevancy=Not Taken into Consideration

	Mandatory	Non Mandatory but Desirable	Not Taken Into Consideration
Distance to Bus Stop			
Distance to Main Road			
Distance to Train Station			
Distance to Airport			
Distance to Green Area			
Distance to Supermarket			
Distance to Sports Facility			
Distance to Healthcare Center			
Distance to City Center			
Distance to University			
Population Average Age in de Area			
Population Density in the Area			

Figure 7. *Mandatory, non-mandatory and not taken into consideration classification criteria*

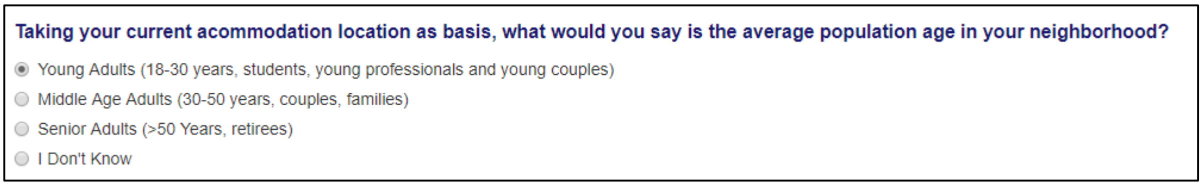
The next step to implement the LSP method refers to the definition of the attribute criteria. An attribute criteria reflects the decision maker's requirements that the input has to satisfy; these requirements are expressed as functions that show the level of satisfaction with each attribute. Since attribute criteria is expressed in a two axis chart, the information that feeds such plot must be obtained in two different sections of the survey.

The "x" axis of the attribute criteria chart refers to respondent's status quo, in other words, it depicts the actual situation of the student. In this survey, it was possible to combine accessibility and amenities questions into one section of the survey, however, due to the nature of the answers, the population category had to be set in two other levels of the questionnaire. Such divisions can be seen in figure 8, 9 and 10.


Taking your current acommodation location as basis, how long does it take to get by bike to the following destinations?

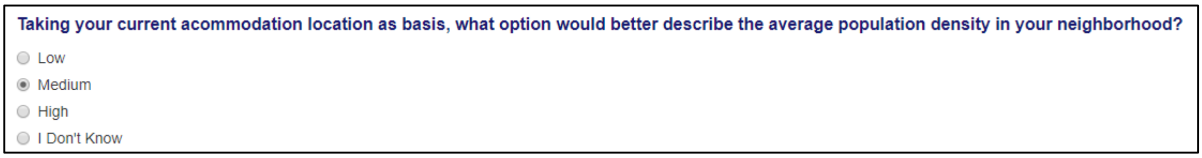
	< 5 Minutes	5-10 Minutes	11-15 Minutes	> 15 Minutes	I Don't Know
Nearest Bus Stop	●	○	○	○	○
Closest Main Road	●	○	○	○	○
Nearest Train Station	●	○	○	○	○
Closest Airport	○	○	○	●	○
Nearest Green Area	●	○	○	○	○
Closest Supermarket	○	●	○	○	○
Nearest Sports Facility	○	●	○	○	○
Closest Healthcare Center	○	○	●	○	○
City Center	○	●	○	○	○
University	○	●	○	○	○

Figure 8. *Survey: travel times*


Taking your current acommodation location as basis, what would you say is the average population age in your neighborhood?

● Young Adults (18-30 years, students, young professionals and young couples)
○ Middle Age Adults (30-50 years, couples, families)
○ Senior Adults (>50 Years, retirees)
○ I Don't Know

Figure 9. *Survey: neighborhood average population age*

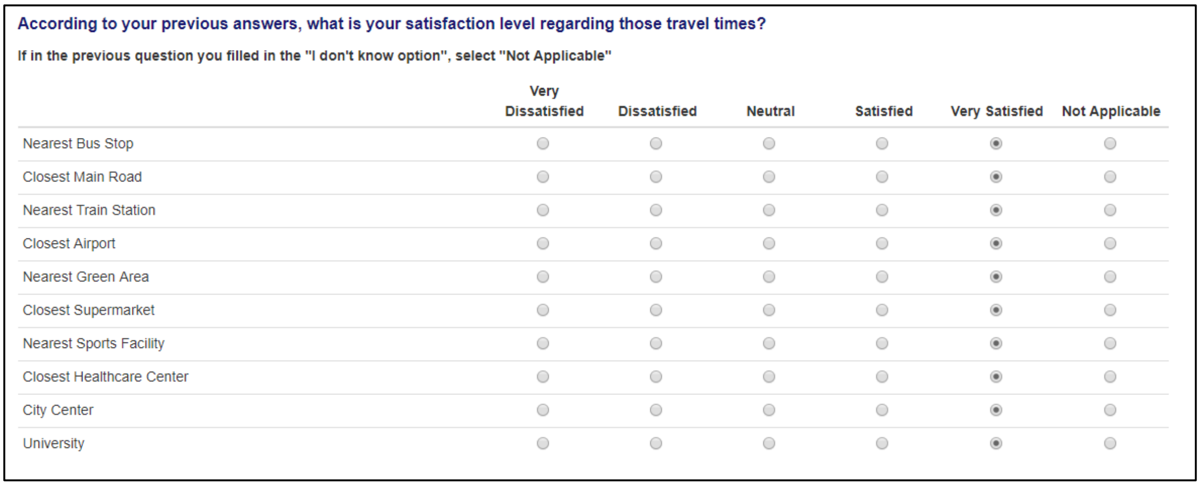

Taking your current acommodation location as basis, what option would better describe the average population density in your neighborhood?

○ Low
● Medium
○ High
○ I Don't Know

Figure 10. *Survey: neighborhood average population density*

It is important to note that in all the previous questions of the survey, the "I Don't Know" option was included. This addition deviates from the regular LSP approach, however, it was included in the survey to motivate respondents to continue with the exercise.

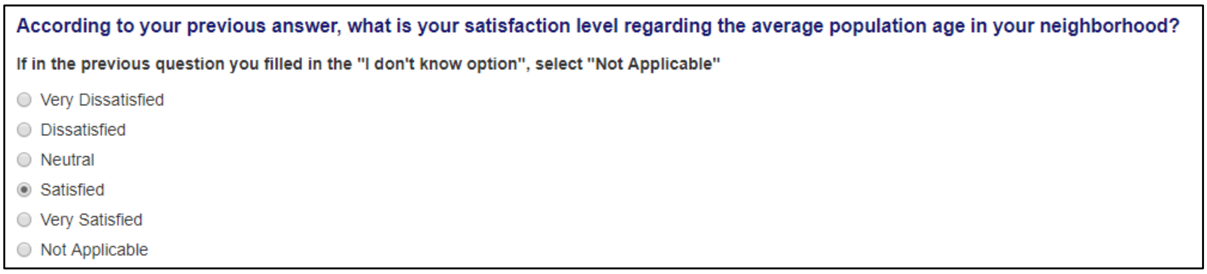
Regarding the "y" axis of the attribute criteria plot, it refers to the suitability of the attribute. In the particular case of this research's survey, suitability is related to satisfaction, where a high satisfaction level reflects a high input suitability. To evaluate satisfaction a 5 levels scale was implemented, this scale ranged from very dissatisfied to very satisfied, going through dissatisfied, neutral and satisfied categories. Due to the incorporation of the "I Don't Know" option in the previous section of the survey it was irremediable to add a "Not Applicable" level. In figures 11, 12 and 13 such scale is shown:


According to your previous answers, what is your satisfaction level regarding those travel times?

If in the previous question you filled in the "I don't know option", select "Not Applicable"

	Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied	Not Applicable
Nearest Bus Stop						
Closest Main Road						
Nearest Train Station						
Closest Airport						
Nearest Green Area						
Closest Supermarket						
Nearest Sports Facility						
Closest Healthcare Center						
City Center						
University						

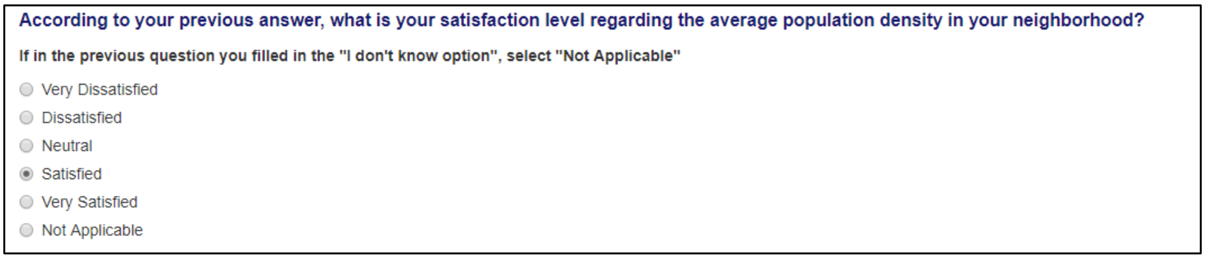
Figure 11. *Survey: travel times satisfaction*


According to your previous answer, what is your satisfaction level regarding the average population age in your neighborhood?

If in the previous question you filled in the "I don't know option", select "Not Applicable"

Very Dissatisfied
Dissatisfied
Neutral
Satisfied
Very Satisfied
Not Applicable

Figure 12. *Survey: neighborhood average population age satisfaction*


According to your previous answer, what is your satisfaction level regarding the average population density in your neighborhood?

If in the previous question you filled in the "I don't know option", select "Not Applicable"

Very Dissatisfied
Dissatisfied
Neutral
Satisfied
Very Satisfied
Not Applicable

Figure 13. *Survey: neighborhood average population density*

The next section of the survey relates to the additive structure of the LSP method; the preference aggregation structure aggregates all the elementary preferences and returns as result the overall suitability of the input. The way the structure works is, either using a WPM or a CPA function, which require input of weights that tell the system which attributes have a bigger impact in the overall suitability score.

According to Dujmovic, there are three ways of calculating such aggregative weights: implementing AHP, neural networks or by perception of experts. The AHP was the method selected due to its relative easiness to implement, as well as its capacity to determine consistency ratios, which would help to determine valid and invalid respondents.

AHP requires a definition of decision hierarchy and pairwise comparison matrices, hence the pairwise comparison in the survey was made in 3 levels, in the first one amenities were compared between themselves using a 7 categories evaluation arrangement (very strong, strong, slight, equal, slight, strong and very strong), then population and finally accessibility; afterwards a comparison between the 3 main categories was made. In figure 14 the accessibility comparison matrix is shown

In your opinion, how the following accesibility attributes compare?

	Very strong	Strong	Slight	Equal	Slight	Strong	Very strong	
Distance to Closest Bus Stop	●	○	○	○	○	○	○	Distance to Nearest Main Road
Distance to Nearest Train Station	●	○	○	○	○	○	○	Distance to Closest Bus Stop
Distance to Closest Bus Stop	○	○	○	○	○	○	●	Distance to Nearest Airport
Distance to Nearest Main Road	○	○	○	○	○	○	●	Distance to Closest Train Station
Distance to Closest Airport	●	○	○	○	○	○	○	Distance to Nearest Main Road
Distance to Nearest Train Station	○	○	○	○	○	●	○	Distance to Closest Airport

***Figure 14**. Survey: accessibility attributes*

It is important to clarify how a comparison matrix is read, for instance, the first couple of attributes that are compared in figure 14 are "distance to closest bus stop" and "distance to nearest main road". For this example the respondent answered that the distance to the closest bus stop had a much higher importance for him than the distance to the nearest main road, hence the left "very strong" level was selected.

The final section of the questionnaire addresses the profile of the respondents; as it was mentioned before, this survey was intended towards a specific group of people and the whole purpose of the last section is to confirm such profile, as well as trying to capture data that might indicate a certain trend. In this part of the survey, age, gender, nationality, educational level and zip code were required.

4.3 Tilburg suitability analysis

As it has been stated before, the MCE method chosen to develop a suitability analysis of student's location preferences is LSP. LSP requires inputs of attributes, attribute criteria and attributes weights, such inputs are intended to be obtained from the designed survey.

In the proposed questionnaire, twelve major attributes were addressed; the best way to analyze the status of such attributes is by implementing geographic information systems data analysis, where it is possible to observe the location and availability of student's location preferences.

To be able to implement GIS data, a case study must be carried out. In the Netherlands there are several student cities that have an increasing student market from both nationals and foreigners; according to some private consultancy agencies this student population growth won't stop in the near future. This situation presents investment opportunities in the student housing market which have detonated the construction of several PBSA developments all around the Netherlands.

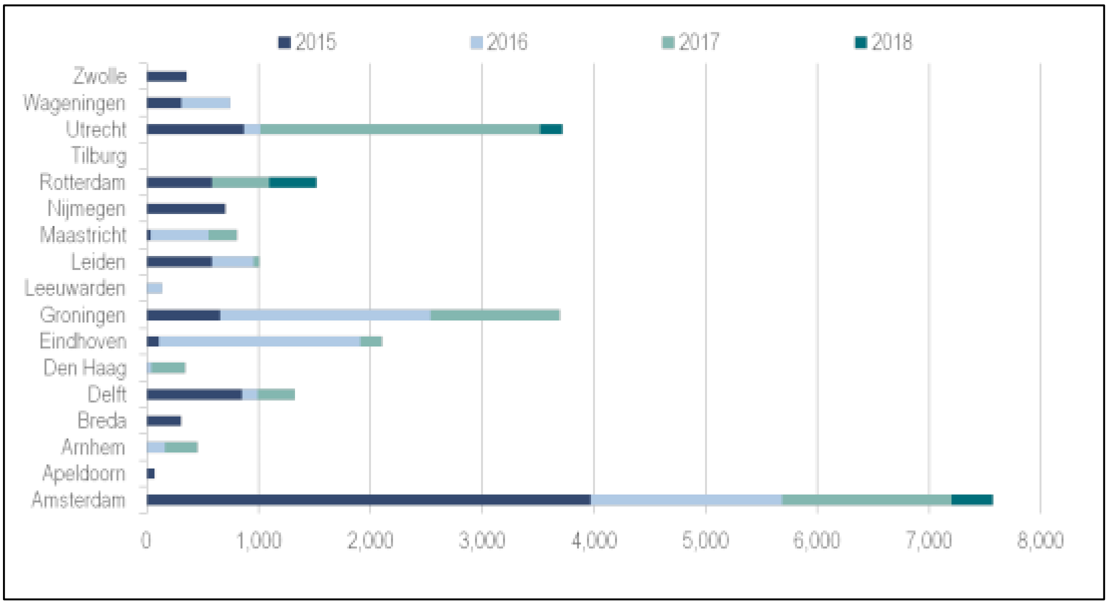


Figure 15. *PBSA's in the Netherlands (Savills World Research, 2016)*

In figure 15 it is possible to notice the amount of student beds that were delivered during 2015 and 2016 as well as the projection of beds that will be delivered in 2017 and 2018, these numbers are based on the volume of approved/under construction projects in Netherlands. From this statistic it stands out the fact that in the city of Tilburg, not any increase in the supply of beds is projected.

Tilburg is the 6th largest city in the Netherlands in terms of population with over 200,000 habitants (NUFFIC, 2016). In the city there are 3 universities of applied sciences: Tilburg University, Avans Hogescholen and Fontys. Together, these 3 schools gather over 27,000 students (NUFFIC, 2016). It is interesting to notice that even when Tilburg has three major universities, and according to some private consultancy firms, the number of students in these universities is expected to grow in the upcoming years (CBRE, 2015; Savills World Research, 2016) there are no investment plans to develop PBSA's in Tilburg. Therefore, the city of Tilburg was selected as a case studio for developing a student housing suitability analysis and as of consequence, a suitability map.

MCE methods are a very specific type of spatial decision support systems that have the ability to provide complex trade-off analysis between choice alternatives with many different factors. When criteria and weights are optimally specified, these MCE methods are powerful tools that allow decision makers to explore, structure and solve complex spatial problems (Laskar, 2013).

The objective of MCE methods is quite simple, they target to get an optimal solution under a set of predefined factors and constraints for analyzing complex trade-offs between different alternatives. In the past, they have been used for spatial optimization models due to its site-specific evaluation capacity (Laskar, 2013).

The Logic Scoring of Preference (LSP) is a multi-criteria evaluation method that aims to analyze complex trade-offs based on accurate modelling of the human evaluation reasoning. The main difference of LSP against any other MCE method is its ability to use any number of input attributes, and generate a resulting suitability score without decreasing the significance of each attribute (Dujmović, De Tré, & Van de Weghe, 2008); in other words, when using LSP is possible to compute mandatory and non-mandatory but desirable attributes without degrading the significance of the mandatory features. LSP is able to model and evaluate different levels of simultaneity and or replaceability, this specific feature of this MCE method mimics ubiquitous components of the human evaluation reasoning which creates a decision process map that resembles more to how humans make decisions (Dujmovic , De Tre , & van de Weghe, 2010)

The fact that it is possible to compute n number of attributes without degrading the significance of certain attributes is the main advantage of implementing the LSP methodology, and it is also the reason why it was selected as the methodology to perform a suitability analysis of student housing in the city of Tilburg

The software used to develop such suitability analysis were ESRI-ARCGIS and IDRISI SELVA. On one hand ESRI-ARCGIS was chosen due to its moderately simple layout and easiness to perform calculations; on the other hand IDRISI SELVA was selected to handle certain situations that ESRI-ARCGIS is not able to perform, such tasks involves classification of areas according to a specific mathematical function, which cannot be done in ESRI-ARGIS.

4.4 Conclusions

In the precedent paragraphs, a detailed explanation of the research approach was made. The methodology followed was determined based on the research main questions and sub-questions.

During the first section of this chapter two topics were addressed: the identification of location factors that are relevant to students (regarding PBSA'S) and a way to include these attributes in a land suitability analysis. It was decided that the best approach was by designing a survey in which certain location attributes were selected based on other author's research. This resulted in a selection of 12 attributes grouped into 3 criteria: Accessibility, Amenities and Population.

The survey was divided into 3 parts; in the first one the importance level of each attribute was asked to respondents as well as travel times to certain important locations and perceptions of their neighborhood. It was also asked the satisfaction level towards those locations and perceptions. In the second section of the survey respondents were requested to make comparisons between all the attributes to understand the importance relationship between these and, as of consequence, obtain attribute weights. In the last part, characteristics of the respondent were asked to validate the target audience of the questionnaire, as well as trying to identify trends.

In the second section of this chapter it was discussed the LSP method as the approach to develop a suitability analysis for PBSA's in the city of Tilburg. This city was selected because of its relatively high number of inhabitants and students, as well as for its minimal PBSA investments, which might represent an opportunity for investors and the municipality to attract more students. In the next chapter an overview of the results of the survey will be presented.

CHAPTER 5

Data Collection

5.1 Introduction

As explained previously, in order reach the research's objectives a survey was prepared. The importance of the survey relies on the results of it. The data acquired during this procedure will serve as input for the LSP method, which eventually will produce a suitability map for PBSA's in the city of Tilburg. In the following paragraphs, the results of the survey will be shown and discussed.

This chapter is divided in five sections. In the first one, sample demographics are shown to understand who the respondents are. Then the level of importance of the compared attributes is presented. Afterwards a discussion about the travel time's results will be shown, followed by the neighborhood characteristics results. Finally, the attributes comparison results are presented in the fifth section of the chapter.

5.2 Sample demographics

Once the survey was dully prepared, it was distributed among students. There were 2 main methods used to distribute the survey: peer to peer distribution (providing a link) and social media posts. The survey was created on the TU/e Berg System and it was available from April 11^{th} to May 23^{th} 2017

During that period of time 1453 people logged into the system and 509 completed the survey, which represents a 35% response rate. The very first question of the survey had the objective of being a filter; it was asked if the person was a student or not, if the response was affirmative the system allowed to continue with the survey. However, if the reply was “no” the system automatically directed the respondent to the end of the survey. Hence, from the 509 people who completed the survey 497 were students.

As it has been stated in previous sections of this report, an LSP analysis was made based on the results obtained from the survey. One step of the LSP methodology requires the calculation of the attribute weights. Dujmovic (2008) establishes that there are three ways for obtaining such weights: AHP, neural networks and opinion of experts. For this research the AHP method was selected to obtain the aggregating weights because of its facility and simplicity to implement.

The AHP is a method, first proposed by Saaty in 1980, in which decision makers systematically evaluate various attributes by comparing them to each other; the method converts these evaluations to numerical values from which a numerical priority or weight is derived for each attribute (Alonso & Lamata, 2006). An important concept of the AHP relates to the consistency of the results. Saaty proposes a method to evaluate for consistency of the results, in which three concepts are involved: consistency ratio (CR), consistency index (CI) and random index (RI). To consider any results valid, Saaty argues that only a comparison matrix is consistent if $CR < 0.1$. A more detailed explanation of the consistency calculation can be found in chapter 3.

Regarding the survey results, the AHP was used to analyze one part of the data. From this analysis a consistency calculation was obtained, from which 133 respondents turned out to have CR’s higher than 0.1, hence these results had to be removed from the analysis. Only removing these results from the AHP part of the survey is not possible because having results from two different samples would introduce bias in the results, therefore, the data from these 133 respondents was removed entirely from the analysis. Therefore, for this research, data from 364 respondents was used.

From the 364 valid inputs 219 were made by man and 145 by woman, which represents a distribution of 60% and 40% respectively. In figure 16 a detailed sample gender distribution is shown.

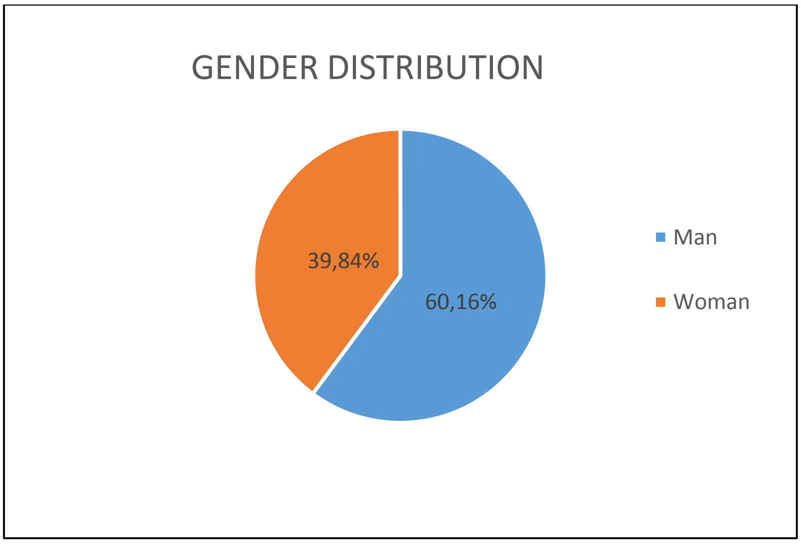


Figure 16. *Corrected Gender Distribution*

With reference to age groups, the sample ranged with participants from 17 to 38 years old.

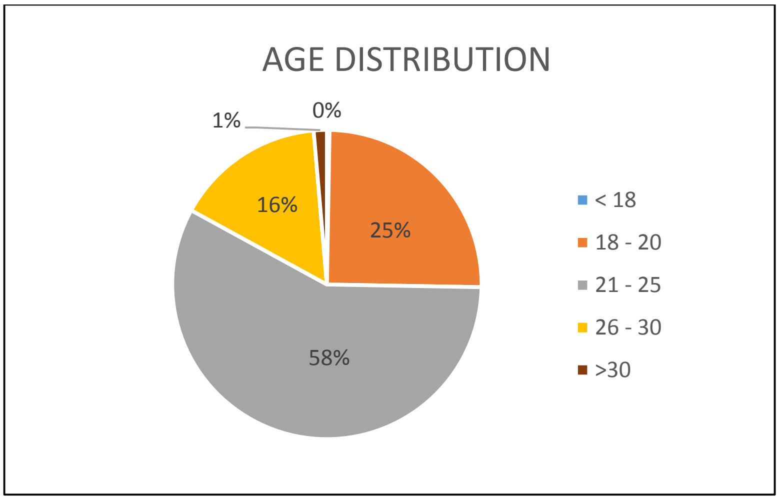


Figure 17. *Corrected Age Distribution*

Figure 17 depicts the sample age distribution, where it is possible to see that the majority of respondents are around 21-25 years old. The 25% of the sample were respondents around 18-20 years old and 16% had around 26-30 years old. There was a small group of respondents that were over 30 years old as well.

As to educational level respondents were registered at, almost half were master's and the other half bachelor's students. The PhD respondents were minimal.

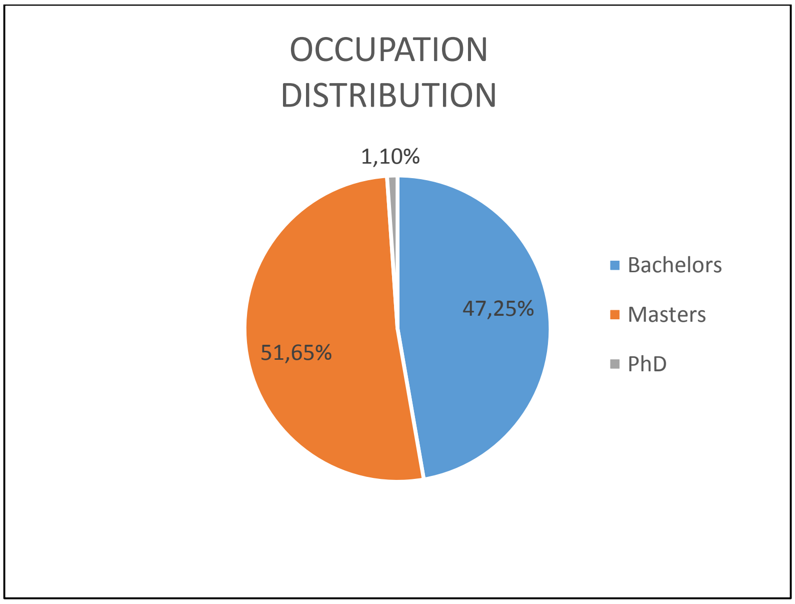


Figure 18. *Corrected Occupation Distribution*

With regards to the respondent's nationalities, the big majority were Dutch, followed by Indians, Mexicans, Chinese and Italians. In total the sample is shaped with respondents from 42 different countries.

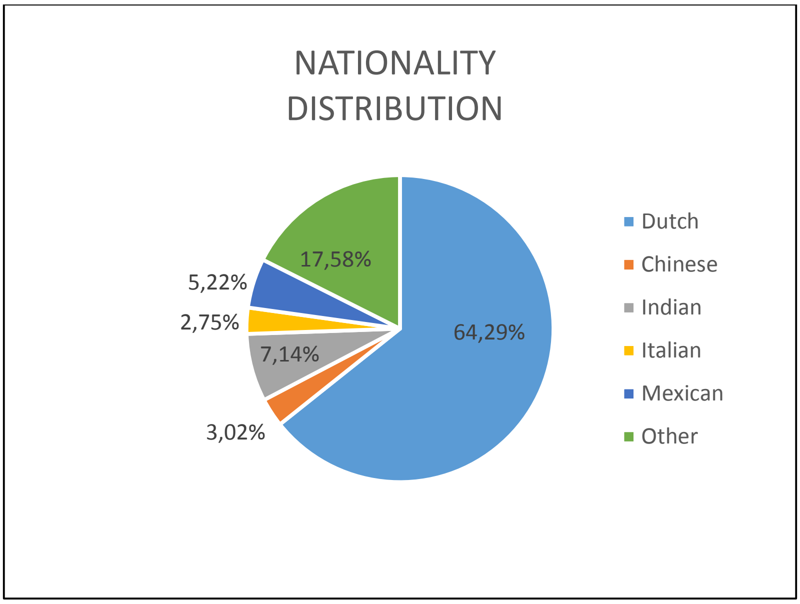


Figure 19. *Corrected Nationality Distribution*

As it was stated before, the sample is shaped with 364 inputs. From these 364 respondents, 60% were males and 40% females. Even though such distribution is fine, it would have been better to achieve a 50/50 distribution to avoid gender bias. Regarding age distribution, the results were as expected, with the majority of respondents being within the 21-25 years old range followed by the 18-20 and the 26-30 years old group. This distribution is in accordance to the occupation distribution where almost half of the respondents were registered at a bachelors program and the other half at a master's program, hence it be said that the target audience was reached (masters and bachelors students). Finally, about the nationalities, a big proportion of the sample are Dutch, followed by several other nationalities groups. Unfortunately, the sample is too small to show any trend related to any other nationality apart from Dutch.

5.3 Mandatoryness and non-mandatoryness of attributes

In the first section of the survey, respondents were asked to classify different location attributes into three different categories: mandatory, non-mandatory but desirable and not taken into consideration. Such classification is required by the LSP methodology. From the 364 valid questionnaires the results are shown in table 3, where all the assessed attributes are grouped in the left column starting by Accessibility (4 attributes), Amenities (6 attributes) and Population (2 attributes)

ATTRIBUTES	MANDATORY	NON MANDATORY	NOT TAKEN INTO CONSIDERATION
BUS STOP	21.15%	44.78%	34.07%
MAIN STREET	10.20%	37.10%	52.70%
TRAIN STATION	39.29%	47.25%	13.46%
AIRPORT	1.60%	12.40%	86.00%
GREEN AREA	8.50%	41.80%	49.70%
SUPERMARKET	59.90%	32.40%	7.70%
SPORT CENTRE	17.30%	47.30%	35.40%
HEALTH CARE	6.00%	28.60%	65.40%
CITY CENTER	47.80%	43.40%	8.80%
UNIVERSITY	78.60%	18.40%	3.00%
NEIGHBORHOOD AVG AGE	3.80%	19.00%	77.20%
NEIGHBORHOOD AVG DENSITY	4.40%	17.90%	77.70%

Table 3. *Mandatory, non-mandatory and not taken in consideration results*

In the previous table, the results from the attribute's importance levels questions are shown. Such results are read as follows: the attribute "bus stop" was considered by 21% of the sample as a mandatory requirement, 45% considered it as a non-mandatory attribute and for the remaining 34% it was not even taken into consideration. Such reading procedure applies to all other attributes. In chapter 6 it will be explained the considerations made to claim the importance level of each evaluated attribute.

5.4 Accessibility and amenities

Afterwards, a status quo evaluation was made. In this part of the survey bicycle travel times to several interest points were asked. Respondents were requested to validate a travel time class to the Accessibility and Amenities attributes of the survey. In table 4 the results of such request can be seen.

BICYCLE TRAVEL TIMES						
POINTS OF INTEREST	< 5 MINUTES	5-10 MINUTES	11-15 MINUTES	> 15 MINUTES	I DON'T KNOW	TOTAL
BUS STOP	318	30	6	1	9	364
MAIN STREET	300	38	12	4	10	364
TRAIN STATION	100	134	85	42	3	364
AIRPORT	1.0	0.0	18.0	281.0	64.0	364
GREEN AREA	199	98	32	10	25	364
SUPERMARKET	297	58	4	3	2	364
SPORT CENTER	115	121	77	26	25	364
HEALTH CARE CENTER	59	105	78	47	75	364
CITY CENTER	96	137	81	46	4	364
UNIVERSITY	55	107	112	84	6	364

Table 4.*Travel times results*

Table 5 can be interpreted as follows: regarding bus stops, 318 respondents assured that the closest bus stop to their home is less than 5 minutes away by bike, 30 said that it was around 5-10 minutes away, 6 affirmed that it was around 11-15 minutes away and 1 estimates that it is further than 15 minutes by bike. From the 364 respondents, 9 claim not to know the bike travel time to the closest bus stop. An important consideration of table 5 is in regards to the "I don't know" class. Such option is not required for the LSP analysis, however it was added to promote respondents to keep answering the survey while mitigating their stress levels if they didn't know the answer for any of the asked questions.

Also, in this section of the questionnaire satisfaction levels related to such travel times were measured. In table 5 satisfaction levels are depicted. As in the previous table, the interpretation of such array is as follows: regarding bus stops, 7 people are very dissatisfied with the travel time towards this accessibility attribute, 10 are dissatisfied, 28 are neutral, 71 are satisfied, 234 claim to be very satisfied with the bike travel time and 14 respondents answered "not applicable". The "not applicable" class was introduced as an option for the people that in the previous section answered "I don't know", however, it is possible to observe that the amount of respondents that selected the not applicable class is different to the number of people who selected the I don't know option in table 4. This difference can be explained by the fact that respondents did express a satisfaction level towards certain attributes even if they did not know the travel times towards such attributes or vice versa.

TRAVEL TIME SATISFACTION							
POINTS OF INTEREST	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	NOT APPLICABLE	TOTAL
BUS STOP	7	10	28	71	234	14	364
MAIN STREET	7	4	50	90	190	23	364
TRAIN STATION	9	22	56	122	152	3	364
AIRPORT	11	10	133	77	62	71	364
GREEN AREA	8	13	62	145	116	20	364
SUPERMARKET	6	6	23	92	234	3	364
SPORT CENTER	6	23	75	123	109	28	364
HEALTH CARE CENTER	8	9	104	104	75	64	364
CITY CENTER	4	26	45	135	149	5	364
UNIVERSITY	14	36	57	123	129	5	364

Table 5. *Travel times satisfaction results*

In chapter 6, these results will be further discussed and certain assumptions will be made to use them as inputs for the LSP method.

5.5 Population

Because of the nature of the questions, accessibility and amenities attributes were combined into two questions. However, the population attributes were assessed in different questions in the survey.

Respondents were asked about their perception regarding their neighborhood average age, as well as the average density. In table 6 and 7 respondents impressions are shown:

NEIGHBORHOOD AVERAGE AGE	
AGE GROUP	COUNT
YOUNG ADULTS (18-30 YEARS)	135
MIDDLE AGE ADULTS (30-50 YEARS)	183
SENIOR ADULTS (>50 YEARS)	13
I DON'T KNOW	33
TOTAL	364

Table 6.*Neighborhood average age results*

NEIGHBORHOOD AVERAGE DENSITY	
DENSITY	COUNT
LOW	18
MEDIUM	223
HIGH	74
I DON'T KNOW	49
TOTAL	364

Table 7. *Neighborhood average density results*

From table 6 it can be understood that 135 respondents claim to live in an area where their neighbors are young (18-30 years), 183 said that they live in a location with middle age (30-50 years) people, 13 expresses that their neighbors are seniors (>50 years) and 33 replied the "I don't know option". As in the previous questions, the "I don't know option" was included to motivate respondents to finish the survey. Regarding neighborhood density, most of the respondents claimed to live in a medium density area, while 74 said that they live in a high density are, 18 in a low density location and 49 answered that they didn't know.

In the next section of the survey, the satisfaction levels towards average neighborhood age and density were requested. Table 8 shows the population attributes satisfaction levels.

NEIGHBORHOOD SATISFACTION							
POINTS OF INTEREST	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	NOT APPLICABLE	TOTAL
AVG AGE	6	15	144	128	36	35	364
AVG DENSITY	2	11	138	138	31	44	364

Table 8. *Neighborhood satisfaction results*

Just as in the previous satisfaction questions, table 8 is read as follows: regarding average age, 6 people claim to be very dissatisfied, 15 dissatisfied, 144 neutral, 128 satisfies, 36 very satisfied and 35 answered “not applicable”. Just as in the accessibility and amenities satisfaction assessment, the not applicable class was incorporated so respondents, that selected the “I don’t know option” in table 7 and 8, could fill this option. However, the numbers between the “I don’t know” and the “not applicable” classes do not match. This difference can be explained by the fact that respondents did express a satisfaction level towards certain attributes.

In chapter 6, these results will be further discussed and certain assumptions will be made to use them as inputs for the LSP method.

5.6 Attributes comparison

In the following section of the questionnaire, pairwise comparisons between selected attributes were made, the objective of doing such pairwise comparisons was to obtain the aggregative weights which indicate the importance of each attribute within the decision process.

As it was mentioned before a 7 levels scale was proposed, this scale ranged from very strong, strong, slight, equal, slight, strong and very strong. Unfortunately during the survey coding process an error was made and the system did not made a distinction between the very strong and the strong category, therefore the 7 levels scale was converted into a 5 level scale (the very strong and strong categories were combined and their entries were added up). In table 9 the results from comparing accessibility attributes are presented:

PAIRWISE COMPARISON						
DISTANCE TO	STRONG	SLIGHT	EQUAL	SLIGHT	STRONG	DISTANCE TO
BUS STOP	179	58	76	26	25	MAIN ROAD
TRAIN STATION	133	64	69	41	57	BUS STOP
BUS STOP	283	43	29	5	4	AIRPORT
MAIN ROAD	27	23	44	52	218	TRAIN STATION
AIRPORT	14	18	63	84	185	MAIN ROAD
TRAIN STATION	304	38	20	1	1	AIRPORT

Table 9. *Accessibility pairwise comparison results*

Table 9 shows the accessibility pairwise comparison results, such comparisons were made between attributes of the same class (accessibility versus accessibility). Table 9 can be read as follows: regarding distance to bus stop and distance to main road, 179 respondents said that a bust stop is strongly more important than the distance to a main road, 58 claimed that the bus stop is slightly more important, 76 assured that they are both equally important, 26 said that the distance to a main road is slightly more important than the distance to a bus stop and finally, 25 people said that the main road was more important. From this comparison it can be concluded that students consider that the distance to a bust stop is more important than the distance to a main road. In chapter 6 the interpretation of such results will be further explained to be used as inputs for the LSP method.

The next attributes to be compared were the amenities. Table 10 presents the accessibility attributes comparison. This comparison was made between attributes of the same class (amenities versus amenities). This comparison table can be read as follows: when comparing green area versus supermarket, 10 respondents said that the green area was strongly more important than the supermarket, 14 said that it was slightly more important than the supermarket, 36 said that they were both equally important, 63 claimed that the supermarket was slightly more important than the green area and 241 expressed that the supermarket was strongly more important than any green area. From this attribute's comparison, it is clear that students prefer having a supermarket nearby than a green area. In chapter 6 the interpretation of such results will be further explained to be used as inputs for the LSP method.

PAIRWISE COMPARISON						
DISTANCE TO	STRONG	SLIGHT	EQUAL	SLIGHT	STRONG	DISTANCE TO
GREEN AREA	10	14	36	63	241	SUPERMARKET
SPORT CENTER	90	80	63	63	68	GREEN AREA
GREEN AREA	112	85	77	57	33	HEALTH CARE CENTER
CITY CENTER	199	66	47	27	25	GREEN AREA
GREEN AREA	14	17	33	51	249	UNIVERSITY
SUPERMARKET	239	71	34	13	7	SPORT CENTER
HEALTH CARE CENTER	1	6	23	50	284	SUPERMARKET
SUPERMARKET	114	105	96	29	20	CITY CENTER
UNIVERSITY	69	63	80	74	78	SUPERMARKET
SPORT CENTER	116	80	104	40	24	HEALTH CARE CENTER
CITY CENTER	153	80	58	41	32	SPORT CENTER
SPORT CENTER	14	16	72	60	202	UNIVERSITY
HEALTH CARE CENTER	15	13	37	89	210	CITY CENTER
UNIVERSITY	264	50	25	18	7	HEALTH CARE CENTER
UNIVERSITY	97	91	100	40	36	CITY CENTER

Table 10. *Amenities pairwise comparison results*

Population attributes were also compared. Since just two population attributes were considered, the comparison table of these attributes is fairly simple. Table 11 shows such comparison, where 34 respondents argued that density is strongly more important than age, 53 said that density was slightly more important, 161 expressed that both attributes are equally important, 58 said that age was more important than density and finally, 58 claimed that population age was more important than density. From this table it can be concluded that both attributes have relatively equal importance for respondents, although, it could also be argued that population age might be more important to students than population density. In chapter 6 the interpretation of such results will be further explained to be used as inputs for the LSP method.

PAIRWISE COMPARISON						
CHARACTERISTIC	STRONG	SLIGHT	EQUAL	SLIGHT	STRONG	CHARACTERISTIC
POPULATION DENSITY	34	53	161	58	58	POPULATION AGE

Table 11. *Accessibility pairwise comparison results*

Once all the attributes were compared, the aggregative weights of the different criteria had to be obtained. In order to get the aggregative weight of each class, a comparison of each was made.

PAIRWISE COMPARISON						
CATEGORY	STRONG	SLIGHT	EQUAL	SLIGHT	STRONG	CATEGORY
ACCESSIBILITY	82	82	111	61	28	AMENITIES
ACCESSIBILITY	205	89	47	13	10	POPULATION
POPULATION	22	19	74	95	154	AMENITIES

Table 12. *Criteria pairwise comparison results*

Table 12 depicts the results of the criteria comparison. When accessibility and amenities were compared, 82 respondents said that accessibility was strongly more important than amenities, 82 claimed that accessibility is slightly more important, 111 expressed that both classes are equally important, 61 said that amenities were more important than accessibility and 28 said that amenities are strongly more important. From such comparison, it is possible to conclude that accessibility has a higher aggregative weight than amenities. This logic was applied to the three comparisons made. . In chapter 6 the interpretation of such results will be further explained to be used as inputs for the LSP method.

5.7 Conclusions

In the previous paragraphs an overview of the survey results was shown. These results will serve as inputs for the LSP method to develop a suitability analysis for PBSA's in the city of Tilburg.

Regarding sample demographics, the majority of respondents were man. Age in the sample ranged from 18-30 years old, however most of the respondents were around 21-25 years old. As intended, most of the sample was registered at either a bachelor or a master's program when the survey was completed; about nationalities, the majority of respondents were Dutch.

About the importance levels of the attributes, respondents claimed different mandatory levels for different attributes, however, the interpretation of such results to be used as inputs for the suitability analysis will be made in chapter 6.

With regards to travel times, respondents were asked to indicate bicycle travel times to certain destinations. 5 categories were created: <5 minutes, 5-10 minutes, 11-15 minutes, >15 minutes and I don't know. Also, related to travel times, respondents were requested to fill in their satisfaction level with those travel times. 7 satisfaction levels were created for such purpose: very dissatisfied, dissatisfied, neutral, satisfied, very dissatisfied and not applicable. Results obtained from this section will serve as inputs for the LSP method.

Because of the nature of the Population criteria, its evaluation had to be made in a separate section of the survey. Therefore 3 tables were created. In the first one respondents were asked to classify their neighborhood average age according to their observation, in the second they were asked to assess the population density and in the final section, a satisfaction assessment with those attributes were made. Such satisfaction assessment was made using the same satisfaction levels than in the accessibility and amenities section.

In the last section of the survey, a comparison between the different assessed attributes was made. It is important to note that such comparison was made only between attributes of the same class (accessibility versus accessibility, etc.) and, afterwards, all the classes were compared. By doing this, aggregative weights can be calculated and its use will be explained in chapter 6.

In the following chapter, the implementation of the LSP method will be explained. Such implementation will be done based on the data acquired in the survey which has been discussed in this chapter.

CHAPTER 6

Logic Scoring of Preferences Implementation

6.1 Introduction

LSP is a MCE method that enables the decision maker to compute many attributes into one decision making tool without losing significance of the inputs. In the following sections of this chapter each step of this methodology implementation will be discussed.

In the first section of this chapter the creation of the LSP attribute tree will be argued, followed by the LSP attribute criteria where data acquired in the survey will be used to generate the attribute criteria. In the third section the LSP aggregation structure will be created and in the last part of this chapter a PBSA suitability analysis in the city of Tilburg will be created.

6.2 LSP attribute tree

According to Dujmovic, the very first step to implement the method is to arrange the decision attributes into an attribute tree that reflects the importance and relevancy of each input.

During the data acquiring process, respondents were asked to classify into 3 categories (mandatory, non-mandatory but desirable and not taken into consideration) different location attributes according to their own beliefs. The results of such comparisons are shown in table 4.

Based on Dujmovic methodology, these decision making factors must be arranged into an attribute tree according to their categorization, where the category "mandatory" reflects high importance, "non-mandatory" represents medium to low importance and "not taken into consideration" low importance (Dujmović, De Tré, & Van de Weghe, 2008). One could even argue that attributes allocated in the "not taken into consideration" category could even be taken out from the attribute tree.

In this step, the decision maker's role is to decide how to classify the data. On one hand it is possible to take a deterministic approach and deciding mandatory and non-mandatory levels of attributes according to the data distribution, where the highest percentage category would determine its classification. According to this approach the attribute classification would be like it is depicted in table 13, where mandatory is represented by "M", non-mandatory by "NM" and not taken into consideration "NTIC".

ATTRIBUTES	MANDATORY	NON MANDATORY	NOT TAKEN INTO CONSIDERATION	CLASSIFICATION
BUS STOP	21.15%	44.78%	34.07%	NM
MAIN STREET	10.20%	37.10%	52.70%	NTIC
TRAIN STATION	39.29%	47.25%	13.46%	NM
AIRPORT	1.60%	12.40%	86.00%	NTIC
GREEN AREA	8.50%	41.80%	49.70%	NTIC
SUPERMARKET	59.90%	32.40%	7.70%	M
SPORT CENTRE	17.30%	47.30%	35.40%	NM
HEALTH CARE	6.00%	28.60%	65.40%	NTIC
CITY CENTER	47.80%	43.40%	8.80%	M
UNIVERSITY	78.60%	18.40%	3.00%	M
NEIGHBORHOOD AVG AGE	3.80%	19.00%	77.20%	NTIC
NEIGHBORHOOD AVG DENSITY	4.40%	17.90%	77.70%	NTIC

Table 13. *Deterministic attribute classification*

By following a deterministic approach there is a loss of data, mainly due to the non-acknowledgment of the results from other categories. Hence, for this research, it was decided to implement a method that, in a way, would take the complete data set into account to determine its classification. The method consists in the generation of a random number from 0 to 1 that is used to check, in a 0-1 scale, where the attribute falls by comparing the random number vs. the attribute's frequencies. For example, an attribute's frequencies are 25% mandatory, 50% non-mandatory and 25% not taken into consideration; a random number is generated and it is 0.45. The mandatory category ranges from 0-0.25, the non-mandatory 0.26-0.75 and the not taken into consideration 0.76-1, therefore the attributed is classified as non-mandatory. According to this methodology, the data obtained in the survey was classified, such process is visible in table 14, where mandatory is represented by "M", non-mandatory by "NM" and not taken into consideration "NTIC".

ATTRIBUTES	MANDATORY	NON MANDATORY	NOT TAKEN INTO CONSIDERATION	RANDOM NUMBER	CLASSIFICATION
BUS STOP	21.15%	44.78%	34.07%	0.2575069	NM
MAIN STREET	10.20%	37.10%	52.70%	0.1927196	NM
TRAIN STATION	39.29%	47.25%	13.46%	0.1090566	M
AIRPORT	1.60%	12.40%	86.00%	0.7440333	NTIC
GREEN AREA	8.50%	41.80%	49.70%	0.1511345	NM
SUPERMARKET	59.90%	32.40%	7.70%	0.4226950	M
SPORT CENTRE	17.30%	47.30%	35.40%	0.1991849	NM
HEALTH CARE	6.00%	28.60%	65.40%	0.3423603	NM
CITY CENTER	47.80%	43.40%	8.80%	0.4409747	M
UNIVERSITY	78.60%	18.40%	3.00%	0.4492809	M
NEIGHBORHOOD AVG AGE	3.80%	19.00%	77.20%	0.2723613	NTIC
NEIGHBORHOOD AVG DENSITY	4.40%	17.90%	77.70%	0.9466717	NTIC

Table 14. *Non-deterministic attribute classification*

For this LSP suitability analysis the classification used was the second, where a random number was generated to account all the acquired data into the decision process.

Now that the attributes are classified, it is important to indicate the mandatory level of each attribute group. The 12 attributes presented in this research represent three main levels: accessibility, amenities and population. The mandatory level of each will depend on the attributes that these general categories contain, where, if in the category there is a mandatory attribute, the level itself will be considered mandatory. Therefore the accessibility and amenities categories were classified as mandatory (+) and population as non-mandatory (-). It is important to note that even though some attributes were appointed as "not taken into consideration" they are being considered as non-mandatory. This consideration has been made to show the LSP capacity to add "n" number of attributes into its decision process without losing significance, however if the decision maker would like to omit these attributes to simplify the model, that is possible due to its low significance. Accordingly, the LSP attribute tree for this analysis is presented in figure 20.

1. ACCESIBILITY (+)
- 1.1 Bus Stop (-)
- 1.2 Main Street (-)
- 1.3 Airport (-)
- 1.4 Train Station (+)

2. AMENITIES (+)
- 2.1 Green Areas (-)
- 2.2 Sport Centers (-)
- 2.3 Health Care Centers (-)
- 2.4 Supermarket (+)
- 2.5 City Center (+)
- 2.6 Universities (+)

3. POPULATION (-)
- 3.1 Average Age (-)
- 3.2 Average Density (-)

Figure 20. *LSP attribute tree*

This LSP attribute tree presents tree branches: two of them are considered mandatory (accessibility and amenities) and one is non-mandatory (population). Regarding Accessibility, four attributes are part of this criteria: bus stop, main street and airport are considered non-mandatory while train station in the only mandatory attribute of this branch. The Amenities criteria is divided into six attributes: three non-mandatory (green areas, sport centers, health care centers) and three mandatory (supermarket, city center and universities). Population is divided into two non-mandatory attributes: average age and density.

The importance of mandatory and non-mandatory attributes is that whenever a certain location is evaluated and it does not comply with the mandatory requirements, the suitability score for such location will automatically be zero, whereas the non-mandatory attributes will either reward or penalize the suitability score, but its noncompliance won't result in a zero suitability score.

6.3 LSP attribute criteria

Once the attribute tree has been defined, the next step in the LSP methodology refers to the generation of individual requirements for each attribute. These requirements are expressed as functions that show the level of satisfaction (y axis) in a 0-1 scale, where 1 represents full satisfaction and 0 null satisfaction. This behavior was explained in chapter 3, in the attribute criteria section.

Individual attribute requirements can be created from expert's advice or literature based, however for this research, the attribute criteria was obtained from the data acquired in the survey.

In order to get the data required to generate such attribute criteria, a cross tabulation between bicycle travel times and travel times satisfaction was created, as well as a cross tabulation between neighborhood average age, neighborhood average density and neighborhood satisfaction. It is important to note that, regarding the bicycle cross tabulations, a transformation from time to distance was made. This transformation is required so the data can be used as inputs in any GIS software. According the Dutch Cyclist Union, the average speed in city bikes in Netherlands is 15 km/h (Dutch Cyclist Union, 2016), therefore the transformation from time to distance resulted into four categories: 1250m (<5 minutes), 2500m (5-10 minutes), 3750m (11-15 minutes) and 5000m (>15 minutes). This new classification implies 4 distance ranges: 0-1250m, 1251-2500m, 2501-3750m and 3751-5000m. In table 15 the distance to bus stop vs. satisfaction cross tabulation is presented.

	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	TOTAL
BUS STOP	1250	5	3	21	55	227	348
	2500	2	4	4	14	6	
	3750	0	2	2	2	0	
	5000	0	1	0	0	0	

Table 15. *Cross tabulation travel times vs. satisfaction*

Table 15 is read as follows: regarding respondents that live within 1250m to a bust stop, 5 are very dissatisfied with such distance, 3 are dissatisfied, 21 are neutral, 55 are satisfied and 227 are very satisfied. This reading applies to each distance class. It is important to note that the amount of respondents that generated this table is 348, this number deviates from the 364 students that filled in the survey. The reason of having this mismatch relates to the people who filled in “I don’t know” and “not applicable” in the travel times and travel satisfaction sections of the survey (Table 4 and 5).

After having all the cross tabulations for all the attributes, they must be translated into a chart, where in the “y” axis the satisfaction level is shown in a 0-1 scale and in the “x” axis the distance ranges must appear. To transform the satisfaction level into the desired scale, two tools are occupied; first a weighted average is calculated using all the values from one distance level and then a standardization process of the results is executed. It is important to note that during the standardization process, it is assumed that the closer to a certain attribute, the higher suitability and vice versa, hence levels with distance 1250m and 5000m have suitability scores of 1 and 0 respectively. In table 16 it is depicted the previous explained process.

	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
BUS STOP	1250	5	3	21	55	227	4.59	1
	2500	2	4	4	14	6	3.60	0.62
	3750	0	2	2	2	0	3.00	0.39
	5000	0	1	0	0	0	2.00	0

Table 16. *Attribute criteria generation*

Afterwards a distance vs. standardized suitability plot is created.

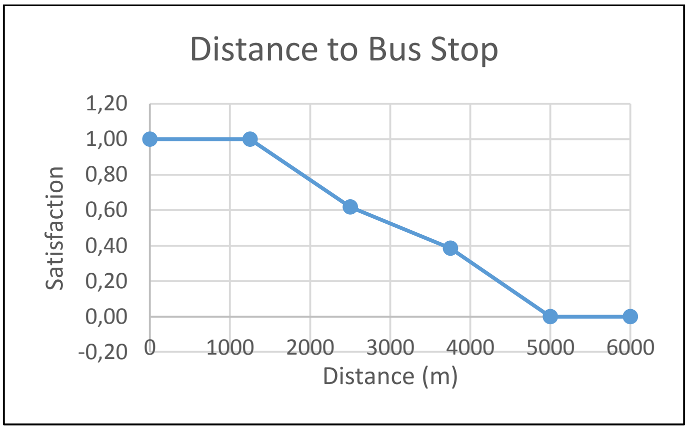


Figure 21. *Distance to bus stop attribute criteria*

In figure 21 it is possible to notice the LSP attribute criteria regarding distances to bus stops, where any area where a bus stop that is located from 0-1250m has a suitability score of 1, from 1250m-2500m the suitability score ranges from 1-0.62, from 2500m-3750m it ranges among 0.62-0.39 and from 3750-500 ranges among 0.39-0. It is understood by this function that any location where the closest bus stop is located 5000m away or further has a suitability score of 0. The purpose of feeding the LSP model with such attribute criteria is to make a more robust model that is capable of setting different suitability levels for different attributes. In this research, 12 different attribute criteria were created, all of them are available at the appendix section of this paper.

6.4 LSP aggregation structure

During the first two steps of the LSP implementation all the efforts are focused on the data and how it will be used as an input. Now it is turn to create the structure by which the system will evaluate the overall suitability of each location.

As it has been explained before, the LSP methodology revolves around soft computing concepts where the andness and orness of inputs is taken into account to select the appropriate aggregator. Soft Partial Conjunction (SPC) aggregators (C-- and C-) are used to aggregate inputs that its mandatory level is low; the choice between C-- and C- is up to the decision maker and its selection must reflect the importance of the aggregated attributes to the overall suitability analysis, whereas C-- indicates low non mandatory level of the attributes and C- higher non mandatory level.

Regarding Hard Partial Conjunction (HPC) aggregators (C-+, CA, C+-, C+ and C++), these are used to aggregate inputs with high mandatory level and, as with the SPC aggregators, the selection between C-+, CA, C+-, C+ and C++ is up to the decision maker and it must reproduce the mandatory level of each attribute.

Following these principles, the aggregation structure for the Tilburg student housing suitability analysis was created. In figure 22 such structure is shown.

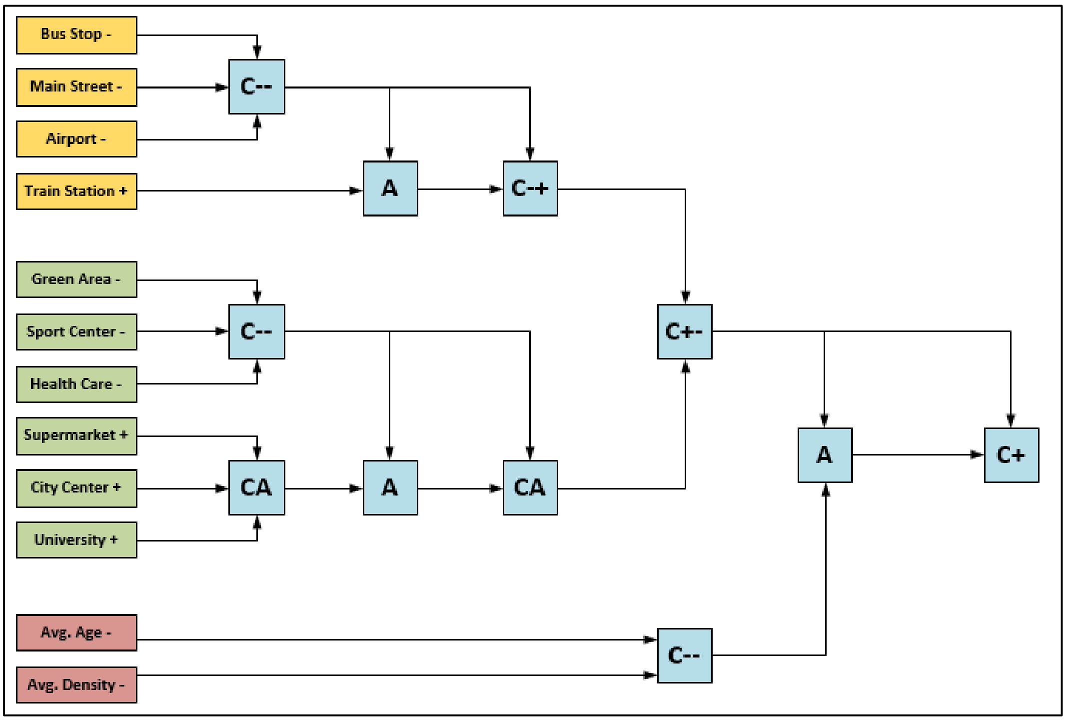


Figure 22. *LSP attribute tree without weights*

In figure 22 the LSP suitability analysis is depicted. Accessibility (yellow), amenities (green) and population (red) attributes are aggregated using soft computing aggregators. Regarding the Accessibility inputs (yellow), first the three non-mandatory attributes (Bus Stop, Main Street and Airport) are aggregated using the C--aggregator. The C-- aggregator was selected due to the non-mandatory classification of the inputs. C- was not chosen because it would reflect a higher importance of the inputs, and, according to the survey data, in all the three attributes if the non-mandatory and the not taken into consideration percentages would be added (table 14), it would result in over 75% of people who expressed a low importance level of those attributes. Then the non-mandatory and the mandatory inputs are added, which requires the utilization of Conjunctive Partial Absorption (CPA). CPA dictates the use of a Neutrality (A) and a Hard Partial Conjunction (HPC) aggregator (C-+). The C-+ operator was used because the train station is considered a mandatory input, even when, according to the frequency table (table 14), the majority of respondents considered It was not mandatory. Therefore, the lowest HPC aggregator was used.

Next, the Amenities attributes were added up. As with accessibility, the non-mandatory ones were aggregated (green areas, sport centers, health care centers) using the C-- aggregator instead of the C-. The reason of this choice is the same as in the previous case; the majority of respondents indicated that these amenities were not so important to them and using a C- aggregator would not reflect that feeling. About aggregating the mandatory inputs, in this case the CA aggregator was used instead of the C-+ mainly due to the fact that these attributes indeed represent mandatory requirements; higher aggregators (C+-, C+ and C++) were not considered because typically these are used for higher aggregation levels. Finally, mandatory and non-mandatory attributes were combined using A and CA aggregators. The CA aggregator was elected because in this part of the model low requirement and high requirement attributes are being combined, hence preferring any aggregator higher than CA would not make sense.

Respect to the next process of the diagram, aggregating accessibility (C-+) and amenities (CA) is produced using the C+- aggregator. The big reason behind this election relates to a higher aggregation level as well as representing the mandatory categories of the suitability analysis.

In order to get an overall suitability, combining accessibility, amenities and population attributes must be done, hence to aggregate neighborhood average age and neighborhood average density the C-- aggregator was utilized. As in previous cases, this aggregator was used due to the low importance level of such inputs. Finally, to combine the aggregated accessibility/amenities (+) with population (-) a high level HPC aggregator was chose (C+).

As it can be read in the previous paragraphs, the aggregator selection process relies more in the decision maker criterion rather than at any specific methodology, however it is important to understand the implication that each aggregator has. This characteristic of the LSP method gives certain flexibility to the analyst mainly because allows to adjust the suitability criteria according to the needs or desires of the decision maker. There is no specific validation process for the selection of the aggregators, instead, an analysis of the requirements of the suitability map must be made and based on it the aggregators must be selected.

Even though an aggregation structure has been created, it still misses one important component, the weights of each attribute. Without the weights, the aggregation structure is useless. According to Dujmovic, the weights can be calculated in either 3 ways: neural networks, expert's opinion or AHP. This report opted for the third option based on the pairwise comparison section from the survey. The AHP is a methodology that generates weights for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria (Saaty T. L., 1980). In the following paragraphs a brief explanation of how to implement this methodology will be shown.

The first step to follow is the transformation of the survey acquired data into a pairwise comparison matrix. In table 17 an example of how the data was collected is presented. It can be seen that there are 5 comparison levels and 6 comparisons. Respondent's answers are shown in gray.

PAIRWISE COMPARISON						
DISTANCE TO	STRONG	SLIGHT	EQUAL	SLIGHT	STRONG	DISTANCE TO
BUS STOP						MAIN ROAD
TRAIN STATION						BUS STOP
BUS STOP						AIRPORT
MAIN ROAD						TRAIN STATION
AIRPORT						MAIN ROAD
TRAIN STATION						AIRPORT

Table 17. *Accessibility pairwise comparison input*

To arrange the data into a pairwise comparison matrix it is important to link each comparison level with a numerical value. Thus, the strong level is represented by 5, slight by 3 and equal by 1. According to this scale a comparison matrix was created in table 18

ACCESIBILITY	BUS STOP	TRAIN STATION	AIRPORT	MAIN ROAD
BUS STOP	1		5	5
TRAIN STATION	3	1	5	
AIRPORT			1	0.20
MAIN ROAD		0.20		1

Table 18. *AHP incomplete pairwise comparison matrix*

It is relevant to note that when comparing airport vs. main road, the respondent expressed its preference of main road over the airport, therefore in the matrix such behavior is represented by the reciprocal value 1/5=0.2. The same applies to main road versus train station.

Once this initial matrix is generated, the missing digits are filled with the reciprocal values, in table 19 the complete comparison matrix is shown:

ACCESIBILITY	BUS STOP	TRAIN STATION	AIRPORT	MAIN ROAD
BUS STOP	1	0.33	5	5
TRAIN STATION	3	1	5	5
AIRPORT	0.20	0.20	1	0.20
MAIN ROAD	0.20	0.20	5.00	1

Table 19. *AHP complete pairwise comparison matrix*

The next step to obtain the ranking values, involves to raise the matrix to powers that are successively squared each time; afterwards row sums are calculated and normalized. This mathematical process is known as obtaining the eigenvector. The eigenvector calculation is performed as many times as necessary until the difference between two consecutive row sums is smaller than a prescribed value (usually four decimal values). Table 20 depicts this process.

ACCESIBILITY	BUS STOP	TRAIN STATION	AIRPORT	MAIN ROAD	EIGENVECTOR	WEIGHTS
BUS STOP	40326.25778	23765.90222	242550.5185	105546.1452	412188.8237	0.3046
TRAIN STATION	68398.64889	40326.25778	411582.5778	179004.8711	699312.3556	0.5168
AIRPORT	7160.194844	4221.845807	43113.81333	18746.70933	73242.5633	0.0541
MAIN ROAD	16463.30	9702.020741	99085.65	43113.81333	168364.7905	0.1244

Table 20. *Accessibility weights calculation*

Finally, the last step relates to the evaluation of the result's consistency. It involves the calculation of three variables: Random Index (RI), Consistency Index (CI) and Consistency Ratio (CR). Any CR higher than 0.1 indicates that the input data is not consistent, and therefore is not reliable. More information about these variables can be found in the 3rd chapter of this report.

This AHP procedure was executed with each entry from each respondent using a computational package, from the 497 entries 133 had a CR higher than 0.1, thus, those inputs were erased from the data set, which left this research with 364 inputs. To add up all those different weights and present only one weight criteria the geometric mean was calculated. The geometric mean indicates the central tendency or typical value of a set of numbers by using the product of their values, rather than their sum as the regular arithmetic mean does. By using such tool, the overall weights were obtained. Table 21, 22, 23 and 24 show all the aggregated weights.

ACCESSIBILITY	WEIGHTS
BUS STOP	0.3076
MAIN STREET	0.2069
AIRPORT	0.1192
TRAIN STATION	0.3663

Table 21. *Accessibility attribute weights*

AMENITIES	WEIGHTS
GREEN AREA	0.1148
SPORT CENTER	0.1243
HEALTH CARE CENTER	0.0913
SUPERMARKET	0.2487
CITY CENTER	0.1856
UNIVERSITY	0.2352

Table 22. *Amenities attributes weights*

POPULATION	WEIGHTS
AVG. AGE	0.5
AVG. DENSITY	0.5

Table 23. *Population weights*

CRITERIA	WEIGHTS
ACCESIBILITY	0.431
AMENITIES	0.3599
POPULATION	0.2091

Table 24. *Criteria weights*

The aggregating weights from table 21, 22 and 23 represent the weight each attribute has within its own class. The weights that are shown in table 24 represent the weight each criteria has. As a note, the weights from the population category were not obtained using the AHP methodology because such method requires a comparison matrix of at least second order; in the case of the population category its comparison matrix was a first order matrix, therefore the weights were assumed 50/50 based on the results of the survey.

Once all the weights were calculated, it was possible to add them into the LSP aggregation structure. In figure 23 the final aggregation structure is shown.

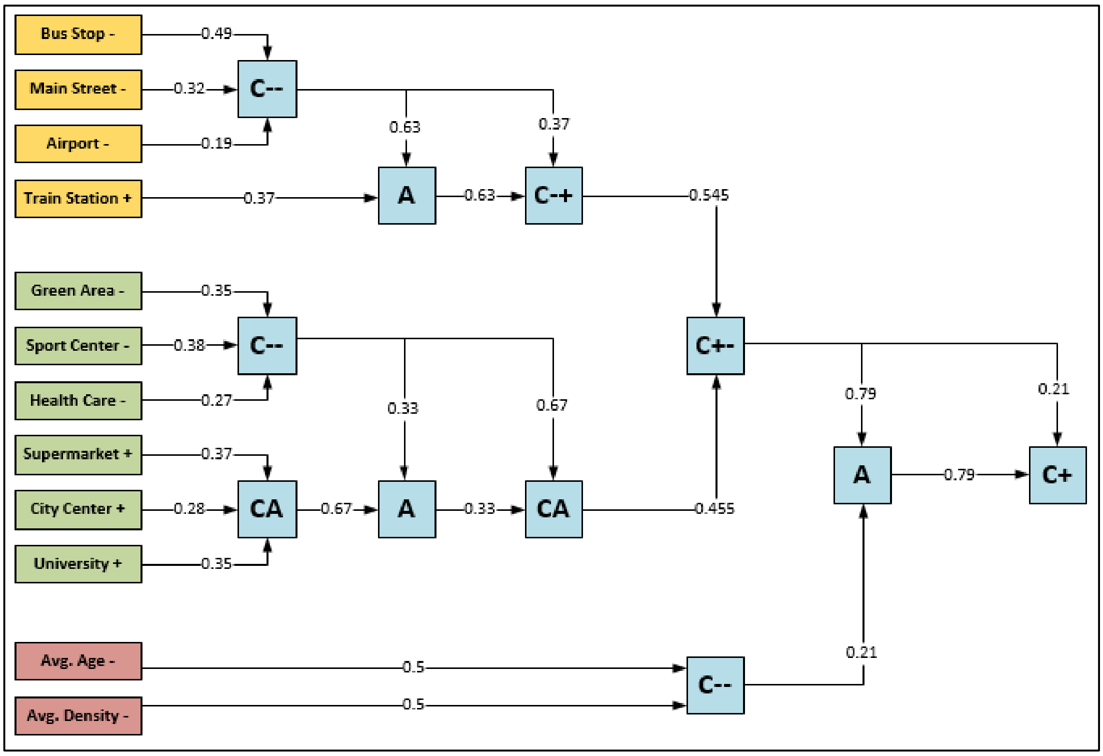


Figure 23. *Student accommodation aggregation structure*

A normalization process of certain weights had to be performed in order to comply with the LSP regulation that requires the inputs weights of each aggregator to sum 1. For example, in the accessibility section from figure 23, the non-mandatory attributes are aggregated, where their AHP weights are 0.3076 (bus stop), 0.2069 (main street) and 0.1192 (airport), if these weights are summed, the result is 0.6337, which matches with the outcome weight of such aggregation, however for the C-- aggregator it does not add 1, hence a normalization process is performed resulting in 0.49, 0.32 and 0.19 respectively. This normalization process repeats itself several times over the entire structure. Another consideration in this LSP tree can be noted at the CPA aggregators (neutrality [A] and a HPC aggregator), LSP requires to invert the weights at the second aggregator.

With the aggregation structured finished, it is possible to compute all the information into a GIS software.

6.5 Suitability map

To show tangible results of the LSP capacity a case study was prepared in the city of Tilburg. Before asking any software to run any sort of suitability analysis, it is crucial to first look for the shapefiles with which the GIS software will work. Hence, twelve different shapefiles were obtained from different sources (available at the appendix section). There are three type of shapefiles: point files, lines files and polygon files. For this report the three types of shapefiles were used.

An important consideration from obtaining shapefiles from different authors is to look after the coordinate system each source is occupying, and, if needed, make the pertinent coordinates projections.

Once the coordinate system was standardized through all the shapefiles, the attribute criteria (created during the second LSP implementation step) had to be applied on to each shapefile to create a raster data file. During this process, two software were occupied. First, ESRI ARCMAP was used to open the shapefile and generate a distance classification per attribute. In figure 24 and 25 this process is visible for the bust stops attribute.

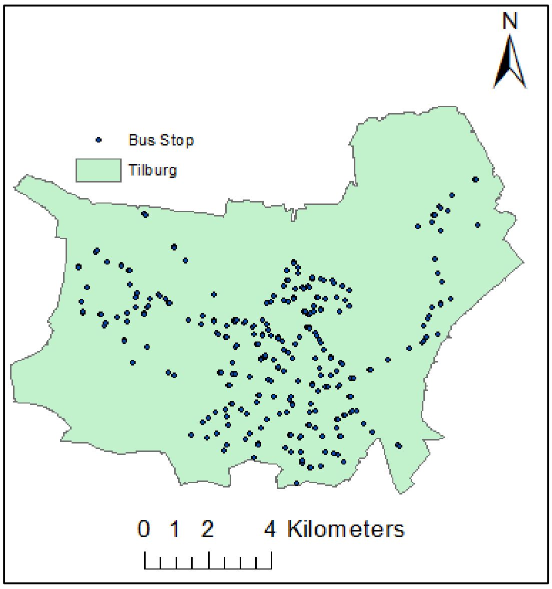


Figure 24. *Tilburg's bus stops*

Figure 24 shows the contour of the city of Tilburg as well as all the available bus stops in the territory. This map was used as input to create the arrangement shown in figure 25, where the Euclidean distance to all the bus stops is calculated.

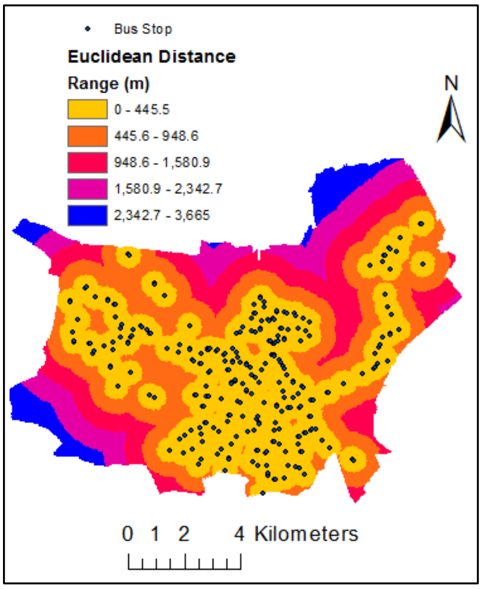


Figure 25. *Tilburg's suitability based on distance to bus stops*

The spatial tool Euclidean distance was used to perform such analysis. This tool calculates the Euclidean distance to the closest source using a range of values, hence this map does not represent the attribute criteria that the LSP methodology requires, therefore this raster data map was imported to IDRISI SELVA, where it is possible to compute the user's preference classifying criteria. In IDRISIS's environment, it is possible to compute functions into the classification criteria through the fuzzy set membership function tool.

After the reclassification done in IDRISI SELVA, a raster map with the bus stop attribute criteria function was created and exported back to ESRI ARCMAP

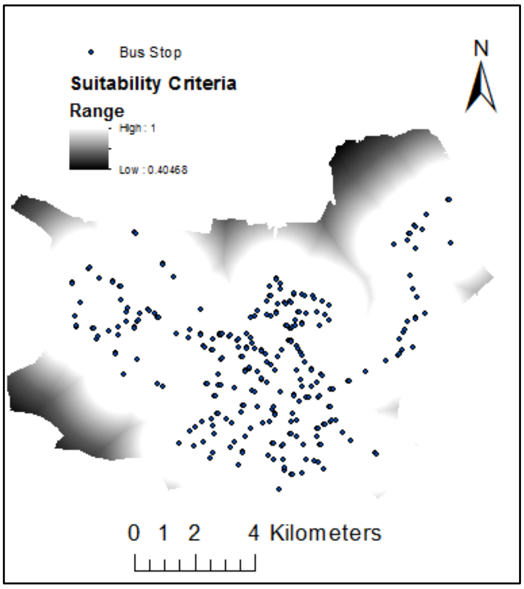


Figure 26. *Tilburg's suitability based on distance to bus stops fuzzy membership criteria*

Figure 26 shows the raster input file that ARCMAP requires to run any calculation. It is possible to observe different suitability levels (for distance to bus stop) and remarkably, the lowest suitability score is 0.41, which means that, according to the criteria, there are no fully unsuitable locations based on the distance to bus stop criteria.

This process was repeated for each of the twelve required inputs. Such maps can be found in the appendix section of this paper. If it is desired, the creation of these maps is not compulsory, and instead all these processes can be modelled directly into IDRISI SELVA, however, by doing this the complexity of the model would increase considerably, making the model harder to work with as well as more difficult to find any errors.

The next step to create a suitability map for student housing in the city of Tilburg is the modelling of the LSP aggregation structure into ARCMAP. This software was selected to develop the suitability map because it has a tool called model builder where it is possible to construct any aggregation structure. It is the decision maker responsibility to model a design that behaves just as the LSP aggregation structure. In the following paragraphs, this process will be explained.

Figure 27 depicts the general aggregation steps to obtain a suitability score. First mandatory and non-mandatory attributes (within the lowest aggregation levels) are combined using the weighted power mean (WPM) function, WPM is used to sum symmetrical attributes (mandatory with mandatory or non-mandatory with non-mandatory), afterwards a partial attribute score is obtained which is then aggregated using the Conjunctive Partial Absorption (CPA) function. CPA is used to combine asymmetrical inputs. Once these first aggregations are completed, the model has the accessibility, amenities and population suitability score. In order to aggregate such criteria a similar process is followed. Accessibility and Amenities are combined first using the WPM function because they are considered mandatory attributes; then, using CPA, Population is aggregated resulting in the overall suitability.

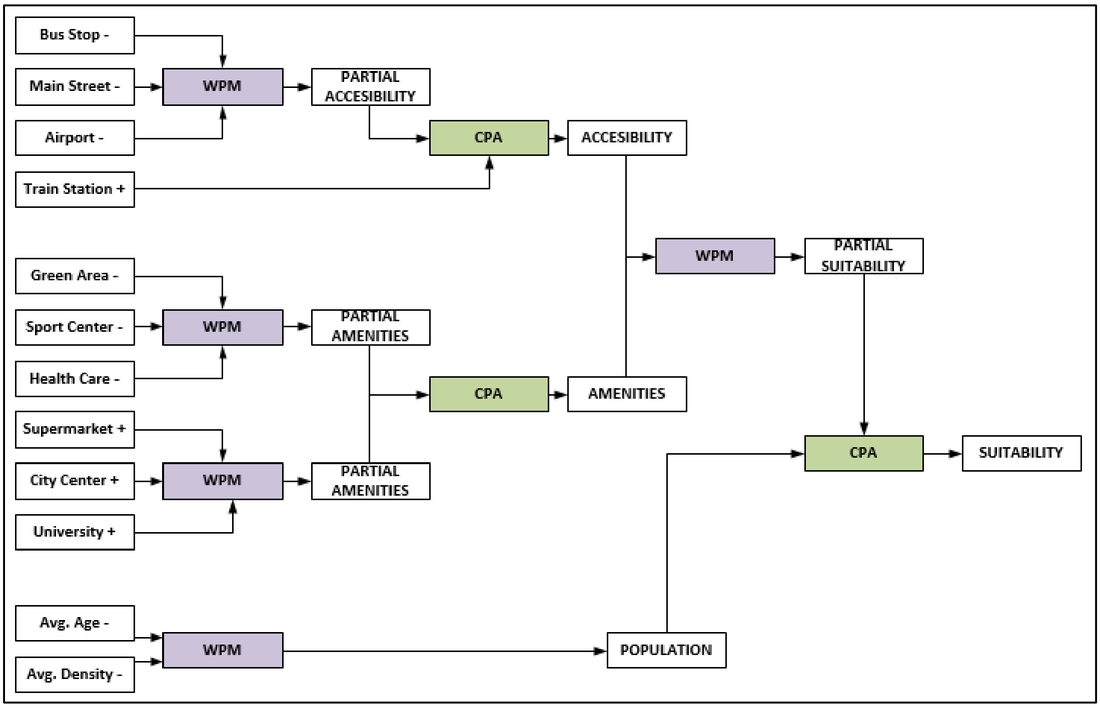


Figure 27. *Aggregation model*

In figure 27 it is shown the way that the software ARCMAP will aggregate all of the attributes to obtain an overall suitability score. The difference between figure 27 and figure 23 is that figure 23 depicts the aggregation structure itself, however, such structure cannot be computed into a GIS software, while figure 27 shows the structure that is modeled in ARCMAP to develop a suitability map based on the structure generated in figure 23.

One other important note about the aggregation model shown in figure 26 relates to the WPM and CPA functions. These aggregating procedures also need to be "translated" into ARCMAP language. Both functions models can be found in the appendix section of this report.

Once the entire LSP aggregative structure has been modeled, a suitability map is obtained as output. Figure 28 shows the PBSA suitability map for the city of Tilburg, created based on the surveyed data.

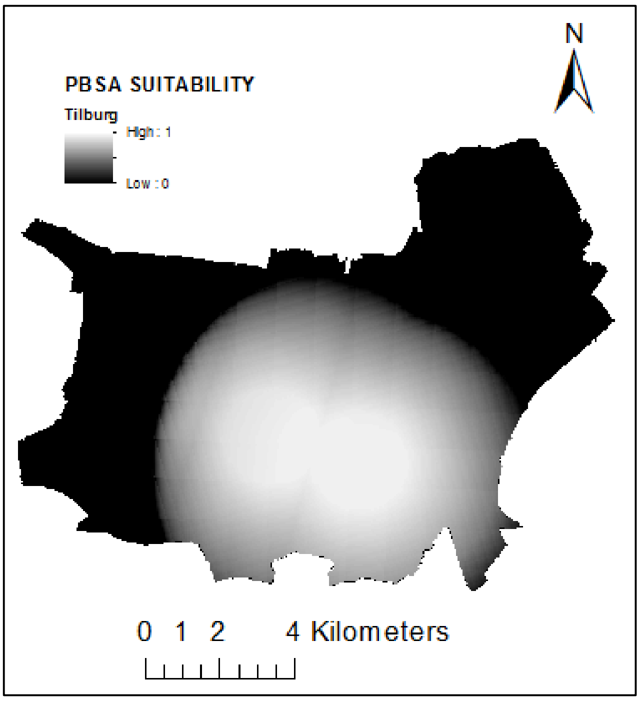


Figure 28. *PBSA suitability map in Tilburg*

The map shown in figure 28 depicts suitable and unsuitable regions to develop PBSA projects in the city of Tilburg. The suitability scale ranges from 0 to 1, where unsuitable regions are represented in black and fully suitable locations are shown in white. The shades in between indicate different levels of suitability among full suitability and full unsuitability. From this map it can be noticed that mandatory attributes have a strong impact in the creation of the suitability map; train station, supermarkets, city center and universities were appointed by respondents as mandatory, these four attributes are only close to each other in one region of the city: near the city center, therefore it is natural to find the highest suitability scores in that area. Regarding the non-mandatory attributes, these also collaborate to the suitability of a certain region, although the main difference between the mandatory and the non-mandatory attributes is that if mandatory attributes requirements are not met, automatically the suitability score plunges to cero, while if the same happens with non-mandatory attributes, the score is affected but not in such a dramatic way. This behavior can be observed in the border of the white circumference shown in figure 28. The white boundary represents where mandatory requirements are met, not fully but enough to generate a score. In this border, non-mandatory attributes help to raise the suitability score, however, passing the white border, the suitability score becomes cero because mandatory requirements are not net and the input of non-mandatory attributes it’s not of importance anymore.

6.6 Conclusions

Logic Scoring of Preferences is a MCE method that enables to compute as many attributes as the decision maker considers appropriate to produce a suitability map, such capacity allows to integrate mandatory and non-mandatory factors into the decision problem, which resembles how humans make decisions. In this chapter the implementation of the LSP method to develop a PBSA suitability map in the city of Tilburg was thoroughly discussed

Regarding the LSP attribute tree, it was decided to generate a random number to decide if each attribute, assessed in the survey, was mandatory, non-mandatory or not taken into consideration. This approach was used because it allowed to take all the inputs into consideration. This method resulted in considering Accessibility and Amenities mandatory criteria and Population as non-mandatory. Within accessibility, only the distance to train station was considered a mandatory attribute, while in amenities distance to university, supermarket and city center were considered mandatory. In the Population criteria, both attributes were considered non-mandatory.

The next step to develop a suitability map under the LSP approach consisted in generating LSP attribute criteria. These are functions by which the model will grade each location according to its suitability towards a certain attribute. To develop such functions a cross tabulation of travel times versus satisfaction had to be made. In total, 12 functions were obtained.

Once the attribute tree and the attribute criteria were defined, the LSP aggregation structure was conceived. The construction of such structure started by the definition of the LSP aggregators. The selection process of such aggregators depends upon the decision maker criterion. Afterwards, the attribute weights were defined based on the AHP.

Finally, a PBSA suitability analysis for the city of Tilburg was developed using two software: ESRI ARCMAP and IDRISI SELVA. ARCMAP was used because of its easiness to model aggregation structures while IDRISI was selected because in his environment it is possible to compute the attribute criteria functions. The resulting map shows several locations within the city that range from 1 to 0 suitability for constructing PBSA. Naturally, the best areas are close to the city center, where mandatory attributes requirements are met.

In the next chapter of this report some other suitability maps will be developed taking in consideration modifications to the original suitability map.

CHAPTER 7

Alternative Suitability Maps

7.1 Introduction

In the previous chapter the implementation of the LSP method was discussed. Starting from the creation of the attribute tree, the definition of the attribute criteria, the selection of the LSP operators to generate the LSP aggregation structure and finally, the conception of a suitability map for PBSA's in the city of Tilburg. In the suitability map shown in chapter 6, 12 attributes divided in 3 categories were occupied as inputs to generate such map. From these 3 categories, accessibility and amenities were considered mandatory and population non mandatory.

In the following sections of this chapter, alternative PBSA's suitability maps for the city of Tilburg will be developed and discussed. First a suitability analysis will be developed only using the accessibility and amenities criteria, then, keeping accessibility and amenities criteria only, a proposition to transform an unsuitable are of the city into suitable for student housing will be made and analyzed.

7.2 Accessibility and amenities criteria only

In table 14 it was shown the method followed to determine if an attribute was considered mandatory, non-mandatory or not taken into consideration. For the suitability map developed in chapter 6, the population criteria was considered for the creation of such map even though it was argued that these attributes were not considered during the student's housing decision process. Apart from not being considered into the decision making process of students, the information found related to population density and population age is not of great detail. CBRE published an overall population density figure for the entire city and an average population age.

In this section, a new suitability analysis will be performed removing the population attributes from the process. Therefore, for this analysis only 10 attributes were considered: distance to bus stop, main street, airport, train station, green area, sport centers, health care centers, supermarkets, city center and universities. By removing the population criteria, a new LSP attribute tree is conceived in figure 29.

1. ACCESIBILITY (+)
- 1.1 Bus Stop (-)
- 1.2 Main Street (-)
- 1.3 Airport (-)
- 1.4 Train Station (+)

2. AMENITIES (+)
- 2.1 Green Areas (-)
- 2.2 Sport Centers (-)
- 2.3 Health Care Centers (-)
- 2.4 Supermarket (+)
- 2.5 City Center (+)
- 2.6 Universities (+)

Figure 29 . *Simplified Attribute Tree*

From figure 29 it can be noticed that, apart from the missing population criteria, all of the other attributes were kept the same. Accessibility and amenities are both considered mandatory criteria (+) and bust stop, main street, airport, green areas, sport centers and health care centers are considered non mandatory criteria (-)

The next step in the LSP framework relates to the definition of the attribute criteria. The same criteria used in chapter 6 can be used for this analysis.

With reference to the aggregation structure, some changes were made to the previous. Removal of any criteria can be made, as long as its criteria weight is considered in the process. In table 24 the original criteria weights were shown: accessibility 0.431, amenities 0.359 and population 0.2091. By removing the population criteria, the accessibility and the amenities criteria had to absorb, in proportional parts, the weight of the population criteria. This process resulted in the accessibility criteria having an overall weight of 0.535 and the amenities criteria 0.465. Another modification of the aggregation structure relates to the overall length of the structure, where, in the original one shown in figure 23, first accessibility and amenities criteria were aggregated using the WPM function and then the population criteria was added by means of the CPA function. Since the population criteria has been removed, the structure is shortened. In figure 30 the new structure is shown.

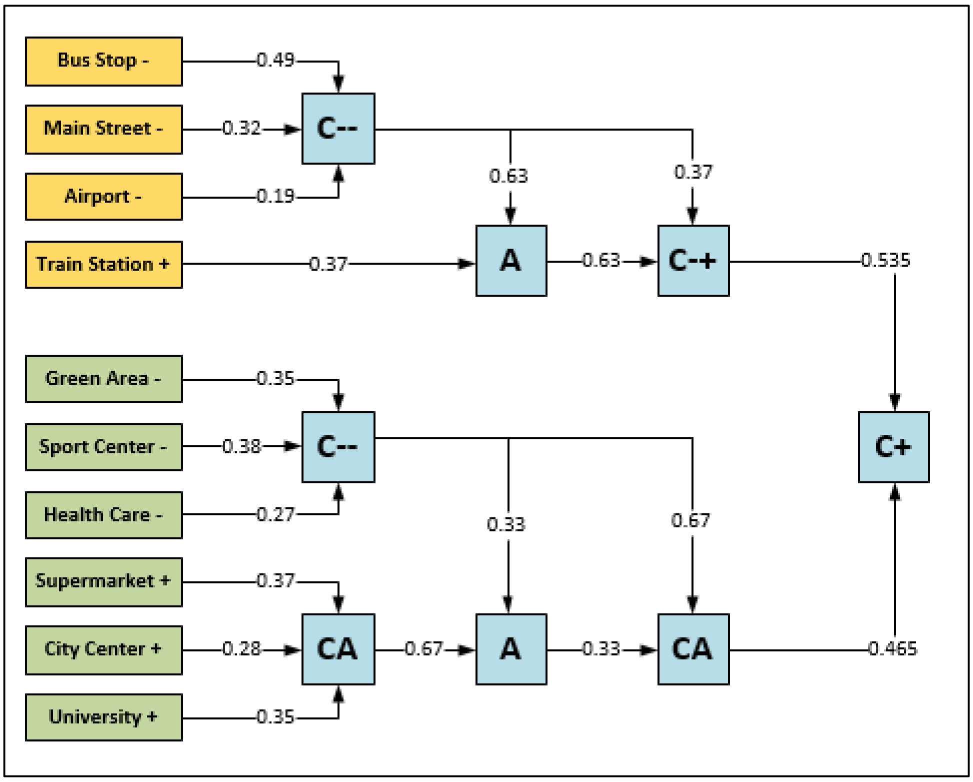


Figure 30. *Simplified LSP Attribute Structure*

One last consideration of removing the population criteria relates to the last operator of the structure. In the original structure (figure 23), the last operator is C+ and the operator that aggregates accessibility and amenities is C+-. By removing the last aggregation section of the structure (CPA function for adding population), the last operator would be C+-, however in figure 30 it can be noticed that it has been changed to C+. This decision was made taking into consideration the new criteria weights, which indicate a higher level of importance of such criteria. From these changes to the LSP inputs, a new suitability map was produced. The simplified suitability map can be seen in figure 31.

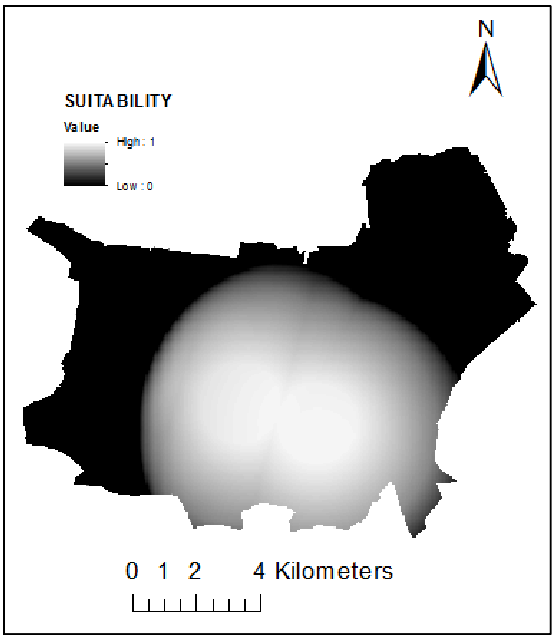


Figure 31. *Simplified Tilburg LSP Map*

The map shown in figure 31 depicts suitable and unsuitable regions to develop PBSA projects in the city of Tilburg considering only accessibility and amenities criteria. As it was expected, the areas with higher suitability scores are located near the city center because in that region all of the mandatory requirements are fully met, while the further away from the city center, the lower the suitability score becomes. Overall it is very complicated to notice differences between the simplified map shown in figure 31 and the complete map depicted in figure 28. The main discrepancy relates to the shade of grays that indicate different suitability scores. It could be said that figure 31 presents areas with higher suitability than figure 28. This behavior can be explained because of the removal of the population criteria, that was not fully meeting the requirements. Population density was considered mid in the entire city, therefore a 0.52 suitability score was assigned to it, while population age was considered mid as well resulting in a 0.5 suitability score. These two attributes were reducing the overall suitability score, resulting in a grayer (less suitable) areas. Since the population criteria was removed, these attributes no longer had any effect in figure 31, resulting in higher suitability scores.

7.3 Improving suitability in Tilburg's west region

From the suitability maps shown in figure 28 and 31 it is possible to observe that the higher suitability regions for developing PBSA's in Tilburg are located near the city center. This behavior can be explained by the availability of mandatory attributes in that specific region. Figure 28 and 31 present an image of the current situation in Tilburg, where if a developer would like to build a PBSA project, it would be advisable to locate it in any of the areas with high suitability score. However, what if such locations are not available for developing such projects? What if Tilburg's municipality would like to develop the west region for student housing? In these cases it is possible to suggest changes that must be performed in the area to make it suitable for PBSA buildings. The recommendations are based on the availability of mandatory attributes, which are the attributes that have a higher impact degree in the suitability of a region.

In this research, four attributes were appointed as mandatory by students: distance to train station, supermarkets, city center and universities. If a non-suitable area would like to be transformed into a suitable area, efforts must be made to satisfy the suitability mandatory requirements. Therefore, for this exercise some changes in the mandatory attributes are proposed to develop a new suitability map.

Regarding the accessibility criteria, distance to train station was indicated by respondents as the only mandatory attribute from this criteria. Fortunately, in the west region of Tilburg there is already one train station, therefore not any change was proposed. Regarding amenities, three were appointed as mandatory: distance to supermarkets, universities and city center. In the west region of Tilburg there are not many supermarkets, hence, if it's the municipality's interest to develop such area, it could provide permits to establish supermarkets in this region. For this exercise, several new supermarket locations were appointed. With reference to the city center attribute, it is important to understand what the city center concept means. The city center is related to shopping, recreational and consumption areas, therefore, if a similar environment would like to be recreated in the west region of Tilburg, a comparable ambiance had to be developed. For this exercise, a new area was selected to be developed as a second city center in the west region of Tilburg. Finally, the most important attribute appointed by students was the distance to a university, in the current state of the city, all the universities are clustered towards the south/center of the city, making the west region totally unsuitable for PBSA, accordingly, if this area would like to be suitable for such developments, new campuses must be built. For this exercise, two universities were considered in the west side of Tilburg. All the maps from these considerations are available in the appendix section of this report.

In figure 32, the resulting suitability map is presented. It is important to note that the aggregation structure used to develop this map, as well as the attribute tree is the same as in the simplified Tilburg LSP map shown in the previous section.

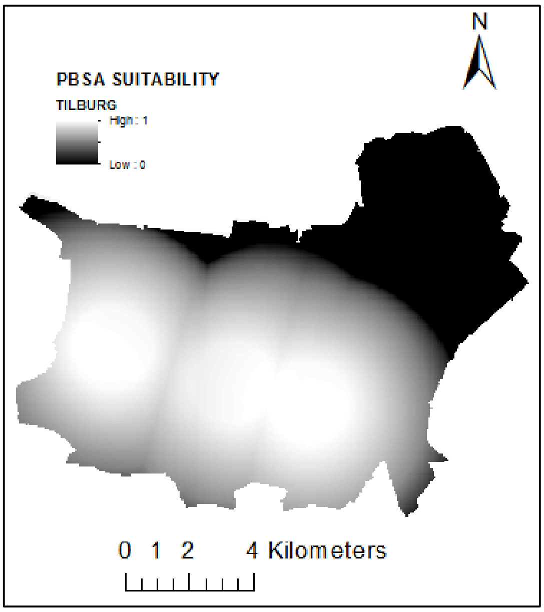


Figure 32. *Improved suitability in Tilburg's west region*

In the previous figure it is possible to observe a new suitability map for developing PBSA in the city of Tilburg. The main difference of this map compared to the previously made relates to the proposed changes in the west region of the City, where additions, in terms of supermarkets, universities, shopping, recreational and consumption areas, were proposed. With these changes it is possible to observe that the west side of the city is suitable to host PBSA developments and it is clear that, in this map, there are three regions with very high suitability scores and, overall, around 65% of the city’s surface is suitable for student housing projects.

7.4 Conclusions

In the previous sections of this chapter, two new PBSA suitability maps of the city of Tilburg were developed. In the first one, the population criteria was removed from the analysis and in the second map, a proposal to develop the west region of Tilburg was made so it could host student housing projects.

Regarding the first map, where the population criteria was removed, it is important to recall the reason of doing this. The information available related to population characteristics was not specific enough to develop a proper suitability analysis. The available information only presented a general population density number (1817 people/m2), instead of a more structured population density by neighborhood as expected, the same situation happened with the population age. Instead of a broken down map with average age per neighborhood, percentages of population age were provided, making no reference to the distribution in the city. These shortcomings forced the procedure into assigning a general population density suitability score of 0.52 (mid density) and 0.5 for population age (mid age) for the entire region. By doing this, the classification objective of the LSP method was undermined. Apart from this, the non-relevancy, for respondents, of population characteristics inspired the idea of developing a suitability map considering only accessibilities and amenities attributes. As expected, the results of this map compared to the original one (12 attributes) are very similar, the subtle differences are noted in the suitability range of each map.

In relation to the improved suitability map, it is crucial to understand the importance of mandatory attributes in the suitability score. For this exercise it was assumed an interest to develop the west region of Tilburg to host PBSA projects, therefore specific proposals were made. These changes circled around three mandatory amenities attributes that were not existent in the area. After implementing these changes, the suitability of the region increased making it ideal for PBSA developments. From these results it can be concluded that the identification of mandatory attributes is of extreme importance to develop unsuitable areas; even though non-mandatory attributes play an important role in the suitability/unsuitability classification, mandatory attributes have higher relevancy in this process.

In the following chapter, general conclusions of the report will be presented. The research's questions and sub-questions will be brought up and based on the findings they will be answered. Also, general recommendations and limitations will be addressed, as well as the societal relevance of this report will be reviewed.

CHAPTER 8

Conclusions and Recommendations

8.1 Introduction

This research presented an overview of the steps followed to develop PBSA suitability maps. By doing this, the research question regarding the identification of location factors that were important to students as well as the question regarding the method to implement such factors in a suitability map were resolved.

In order to achieve the research objectives, a survey was prepared, distributed and the results were analyzed. From those results, suitability maps for development of PBSA's in the city of Tilburg were prepared. This chapter will first dissertate the conclusions of this research, answering the main research question and the sub-questions defined during the introduction of this paper. Thereafter, the societal relevance of the results will be addressed and, to finalize this report, limitations and recommendations for future investigations will be discussed.

8.2 Summary and conclusions

This study aimed to answer the central question: "what location factors are important in student's preference regarding PBSA and how these factors can be included in a land suitability analysis?", although, such question can be criticized for its complexity, a series of sub-questions were proposed to delimit the scope of the study, "what are the location attributes that student's care about?", "what is the level of importance of such location attributes?", "what method, that includes all of the student's location preferences as well as its importance levels, should be used to develop a land suitability analysis?" and "how to implement such method?".

To answer the main research question it was necessary to develop a questionnaire in which location preferences were evaluated. However, the development of such survey could not be done without taking into consideration the method chosen to generate a land suitability map. MCE methods provide tools for analyzing complex trade-offs between choice alternatives with different impacts. Among MCE methods there are many approaches to develop suitability analysis such as SAW, MAU, AHP, etc. Yet, these approaches have been criticized for its oversimplification of the decision making process and, as consequence, the resulting suitability map might not present accurate results. With this in mind, Dujmovic proposed the LSP method, in which attribute importance levels can be computed and the addition of attributes does not affect the significance of each. Under the framework of the LSP method, the questionnaire was created.

In order to understand student location predilections, preference data of 509 respondents was collected in the perimeters of the Eindhoven University of Technology. However, due to inconsistent results, just data from 364 respondents was used. In the survey, respondents were asked to classify a series of attributes (according to their own experience while they were looking for accommodation) into three categories: mandatory, non-mandatory and not taken into consideration. From this exercise several conclusions can be drawn: accessibility and amenities are more important to students than population characteristics, students do not seem to be bothered by high density locations or age differences with their neighbors. Another interesting result was found within the accessibility attributes: not any of the proposed attributes was classified as mandatory for the majority of respondents, which implies that accessibility might not be a very important factor. This behavior can be explained because respondents might use their own bicycle as their principal mean of transportation, rather than any sort of public or private transportation, however, this does not mean that accessibility is totally disregarded, a train station and bus stops were considered by the majority as non-mandatory attributes which implies certain weight in the decision making process. Actually, if mandatory and non-mandatory percentages are combined, the attribute train station has over 85% of the respondents preference, which again implies a considerable weight in the decision making process. Regarding amenities, it is clear that the distance to a university is the most important attribute within this category; supermarket and city center are the second and third most regarded attributes, while sport center, green area and health care center are the least important attributes. It is interesting to note that while sport center was not considered as mandatory factor, it is perceived as desirable, whereas health care center was not considered in the decision process by the majority, the same occurs with green area. For the supermarket attribute, it is clear the importance level for the majority of respondents, although this cannot be said from the city center attribute, where the majority considered it as mandatory but another big percentage of respondents said that it was non-mandatory but desirable.

All in all, it is possible to say that certain trend was found within the survey results. Population characteristics have very low impact in the student housing decision process, while amenities and accessibility attributes have the highest decision weights. Regarding accessibility, proximity to a train station can be a very positive factor, while airport is almost disregarded. Bus stops and main streets can be considered desirable but neither have a high mandatory level. In the amenities category, proximity to a university is required as well as to a supermarket; it can be argued that closeness to the city center can be considered either mandatory or desirable, while green area and sport center are considered desirable attributes and health care center has a low weight in the decision process.

LSP was selected as the MCE method to develop a PBSA suitability analysis in the city of Tilburg. The first step that LSP requires is developing an attribute tree, in this tree accessibility and amenities criteria were considered mandatory and population non-mandatory. Afterwards, definition of functions by which the LSP method can classify locations either suitable or unsuitable were obtained based on cross tabulations of travel times/neighborhood characteristics versus satisfaction. From the resulting cross tabulations it was possible to develop charts that indicate the suitability of the attributes. From these charts it could be concluded that, regarding the accessibility inputs, the closer to any bus stop, train station or main street, the higher the suitability. This does not apply to the attribute “distance to airport” where the results from the survey were inconclusive, mainly because for this attribute, the majority of respondents said that they lived 5000m away or further. With this information it was not possible to compute a function for the attribute, instead, based on literature review of previous research a graph was proposed. Regarding the amenities attributes, the closer to certain amenities the better, but as it was stated before, some amenities were considered more important than others. With respect to the population attributes, students seem to prefer areas with low to mid population density and neighbors that are around 18-50 years old (young and mid age).

Once all the attribute criteria were obtained, an aggregation structure was proposed. The most important step of developing the aggregation structure is the correct selection of the LSP operators. Each operator represent a different level of replaceability and simultaneity; the selection of the operator must reflect the level of importance of the aggregated attributes. In chapter 6, it was explained the reasons behind the aggregators selection. It is imperative to note that the decision maker has a strong influence in the overall suitability results, therefore a good understanding of the operators is required. Another crucial step of the aggregation structure creation relates to the weights of the attributes. The process of obtaining the weights was based on a pairwise comparison section in the survey. The results from this exercise were analyzed using the AHP and through a standardization procedure, they were implemented in the aggregation structure. With the aggregation structure finished, it was possible to obtain a suitability map of the city of Tilburg.

From this suitability map it was concluded that the best regions to develop PBSA projects are near the city center, where universities, train stations and supermarkets are close. These attributes were considered mandatory by respondents. Therefore, it can be said that these attributes dictate whether a location is suitable or not. Non-mandatory attributes increase the suitability of a place, but its not compliance does not dictate non-suitability of the location. A second suitability map for the city of Tilburg was prepared, this map was developed without the input of population attributes. This was decided based on the low significance of the criteria, as well as the poor data found. Results from this map compared to the one that considered all the attributes were found very similar, which enforces the fact that mostly mandatory attributes dictate the suitability of an area. One last suitability map was prepared. In this case the objective of the map was to show that, previously unsuitable locations, can be made suitable if certain attributes are developed in the area. The west side of Tilburg was chosen for this exercise, where supermarkets, city center environment and universities are far away. In the first two suitability maps, this region was considered unsuitable, however, by proposing new supermarkets, recreational, consumption and shopping areas as well as universities, the west side of Tilburg was transformed into a suitable location for developing PBSA projects. The importance of this exercise is that, with the LSP method it is possible to not only understand the current state of a certain location (for developing any kind of project), but also to model fictional scenarios of what it is missing to turn a region suitable for a specific project. This ability can be useful for developers as well as municipalities to better plan urban growth.

One last remark made in this research relates to the aggregator selection for the aggregation structure creation. It was stated that the selection of these operators is based on the importance of the attributes and the responsibility of the correct selection relies on the decision maker. The decision maker selection process can be deemed subjective, thus, the effects of inadequate operators were studied. On one hand, if aggregators that represent very high levels of simultaneity are selected, the resulting suitability map will show very few fully suitable areas, and the overall map will present low suitability areas. On the other hand, if operators with high levels of replaceability are selected, the outcome map will present many areas with full suitability, as well as overall high suitability regions. The correct operator selection comes as a result of an analysis of the attribute's requirements, therefore, the decision maker is advised to fully understand the reasoning behind his operator selection.

Overall, the LSP method presents an interesting way of measuring suitability based on previously acquired data. The method is highly effective and has many advantages and several applications. One issue that the method faces is that it is not fully integrated with computational packages, which makes it harder to implement. However, with time GIS software will fully embrace it. In the meantime, the LSP method can be referred as a way to compute objective and subjective data to produce realistic and reliable suitability maps.

8.3 Discussion and future research

Scientific research is performed to understand how the world around us is functioning. With the results acquired from research it is intended to develop various sectors of the society such as housing industry, education, governmental practices, etc. In the case of this specific study, identification of student preferences has the potential to help developers to understand which areas are more suitable for student housing projects, as well as allowing decision makers, such as municipalities, to better plan ahead the city development, and if required, to serve as a guide to transform specific unsuitable locations into more adequate areas for any purpose.

The relevancy of this research not only relies in the identification of student housing preferences. It also presents an alternative spatial decision making tool that allows to incorporate more factors into the decision making process. LSP has the capacity to model a more robust decision making scenario because it incorporates as many inputs as the decision maker wants to add without losing attribute significance. Of course, this increase in model robustness also comes with an increase in the model creation difficulty, mainly because several new concepts have to be understood as well as the requirement of many data. However, spatial decision making is a topic that must be addressed as best as it can, therefore LSP has the potential to become the standard MCE method used in this field.

This report intended to present a method to develop an attribute criteria by which a developer could use to determine suitable and unsuitable areas to construct PBSA's projects. However, in order to do so, there are certain consideration that must be made.

i. This research was performed in the Netherlands, therefore the application of such criteria is limited to it. If this criteria would like to be used elsewhere, another survey must be made to confirm local students' preferences. Nevertheless, the principles applied in this research are valid elsewhere.
ii. The results presented in previous sections were based on the data of 364 respondents, depending on factors like margin of error and confidence level, this sample can be considered either robust or not robust enough to represent the totality of students in the Netherlands.
iii. PBSA's in the Netherlands have been targeted more towards international rather than Dutch students. Hence, a distinction between Dutch and international preferences might exist. Performing a separate preferences survey for locals and for international students might reveal core inclinations towards different attributes.

Regarding the LSP methodology, there also are some recommendations to be aware of.

i. A full understanding of soft computing aggregators is required to develop a robust suitability map.
ii. The decision maker has the ability to strengthen or relax the LSP criteria according to the chosen aggregators. The proper selection of the aggregators must be based on the degree of replaceability/simultaneity of each attribute.
iii. GIS inputs have to be presented in the same coordinate system, otherwise, imprecisions in the suitability map might arise.
iv. Current GIS software are not fully compatible with the LSP method, hence, special attention must be paid during the modelling phase of the LSP aggregation structure to avoid any type of errors.

With reference to future research, efforts must be taken to further investigate the effects of population factors into the decision making process of students. In this report, the population attributes that were evaluated turned out to be of low significance for student housing choice, nevertheless, the GIS information obtained for such parameters, was not specific enough to properly feed the LSP method, therefore, the population criteria effect on Tilburg's PBSA suitability map cannot be considered accurate.

Another suggestion concerns the applicability of the student housing preference attributes. For this research some accessibility and amenities inputs were selected to perform a suitability analysis. The selection of such attributes was based on literature review from previous authors and the availability of the attributes in the region. Thus, it is possible that for certain locations in the Netherlands extra attributes, which were not considered in this study, exist and are part of the student housing preference decision model. To incorporate these new attributes is fundamental to generate a realistic suitability map, as well as to determine real student housing preference patterns. Once these new attributes are incorporated into the LSP framework, the principles underlying the modeling approach should not be different.

One final discussion of this research is with regards to the applicability of the LSP approach in the interest of municipalities and developers. Currently, several PBSA projects are under construction and many more are planned. The success of these projects can be analyzed as a function of the compliance of the LSP method requirements, where, if mandatory LSP attributes are met, chances are that these projects will turn out profitable. For municipalities and developers it is important to project the success of their investments. Hence, one way of making such predictions can be based on a compliance analysis of the student mandatory attributes in the area/project. If the results of this analysis indicate that mandatory attributes are not being met, efforts must be taken to further develop the area to comply with the students mandatory requirements. By following this procedure, stakeholders gain certainty in the achievement of the project objective.

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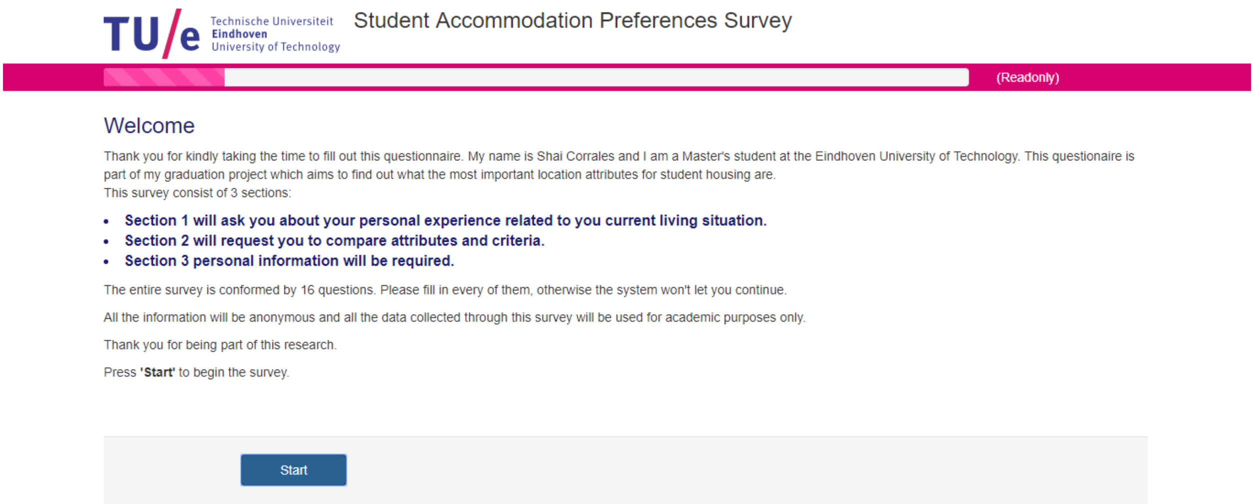
Appendix

A1 Student accommodation preferences survey



Technische Universiteit Eindhoven University of Technology

Student Accommodation Preferences Survey

(Readonly)

Welcome

Thank you for kindly taking the time to fill out this questionnaire. My name is Shai Corrales and I am a Master's student at the Eindhoven University of Technology. This questionaire is part of my graduation project which aims to find out what the most important location attributes for student housing are.
This survey consist of 3 sections:

- **Section 1 will ask you about your personal experience related to you current living situation.**
- **Section 2 will request you to compare attributes and criteria.**
- **Section 3 personal information will be required.**

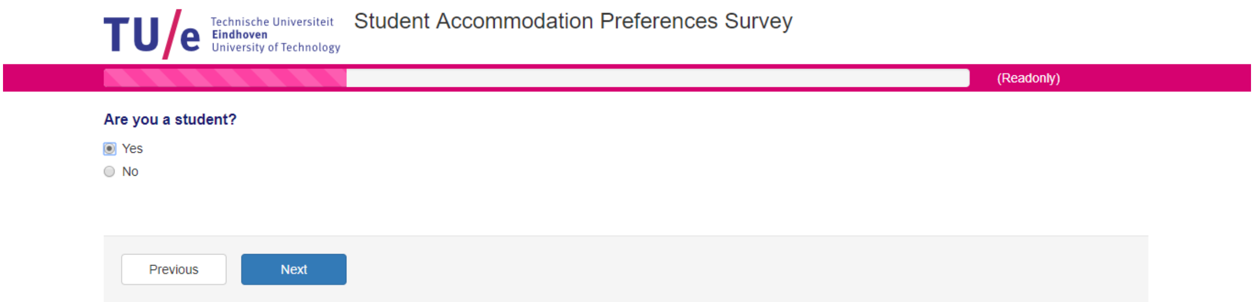
The entire survey is conformed by 16 questions. Please fill in every of them, otherwise the system won't let you continue.

All the information will be anonymous and all the data collected through this survey will be used for academic purposes only.

Thank you for being part of this research.

Press **'Start'** to begin the survey.

Start



Technische Universiteit Eindhoven University of Technology

Student Accommodation Preferences Survey

(Readonly)

Are you a student?

- Yes
- No

Previous Next

TU/e Technische Universiteit Eindhoven University of Technology

Student Accommodation Preferences Survey

(Readonly)

Section 1

In this section you will be asked about your personal experience related to your current accommodation

During the period of time when you were looking for accommodation there were certain location attributes that you might have looked for. From the following attribute list, what was the relevancy of each into your decission process?

High Relevancy=Mandatory

Medium Relevancy= Non Mandatory but Desirable

Low Relevancy=Not Taken into Consideration

	Mandatory	Non Mandatory but Desirable	Not Taken Into Consideration
Distance to Bus Stop	○	○	●
Distance to Main Road	○	○	●
Distance to Train Station	○	●	○
Distance to Airport	○	○	●
Distance to Green Area	○	●	○
Distance to Supermarket	○	●	○
Distance to Sports Facility	○	●	○
Distance to Healthcare Center	○	○	●
Distance to City Center	○	●	○
Distance to University	●	○	○
Population Average Age in de Area	○	○	●
Population Density in the Area	○	○	●

Taking your current acommodation location as basis, how long does it take to get by bike to the following destinations?

	< 5 Minutes	5-10 Minutes	11-15 Minutes	> 15 Minutes	I Don't Know
Nearest Bus Stop	○	●	○	○	○
Closest Main Road	●	○	○	○	○
Nearest Train Station	○	●	○	○	○
Closest Airport	○	○	○	●	○
Nearest Green Area	○	○	●	○	○
Closest Supermarket	○	●	○	○	○
Nearest Sports Facility	○	○	●	○	○
Closest Healthcare Center	○	○	○	●	○
City Center	○	●	○	○	○
University	○	●	○	○	○

According to your previous answers, what is your satisfaction level regarding those travel times?

If in the previous question you filled in the "I don't know option", select "Not Applicable"

	Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied	Not Applicable
Nearest Bus Stop	●	○	○	○	○	○
Closest Main Road	●	○	○	○	○	○
Nearest Train Station	●	○	○	○	○	○
Closest Airport	●	○	○	○	○	○
Nearest Green Area	○	●	○	○	○	○
Closest Supermarket	○	○	●	○	○	○
Nearest Sports Facility	○	○	○	○	●	○
Closest Healthcare Center	○	○	○	●	○	○
City Center	○	○	○	●	○	○
University	○	○	○	○	●	○

Taking your current acommodation location as basis, what would you say is the average population age in your neighborhood?

- Young Adults (18-30 years, students, young professionals and young couples)
- Middle Age Adults (30-50 years, couples, families)
- Senior Adults (>50 Years, retirees)
- I Don't Know

According to your previous answer, what is your satisfaction level regarding the average population age in your neighborhood?

If in the previous question you filled in the "I don't know option", select "Not Applicable"

- Very Dissatisfied
- Dissatisfied
- Neutral
- Satisfied
- Very Satisfied
- Not Applicable

Taking your current acommodation location as basis, what option would better describe the average population density in your neighborhood?

- Low
- Medium
- High
- I Don't Know

According to your previous answer, what is your satisfaction level regarding the average population density in your neighborhood?

If in the previous question you filled in the "I don't know option", select "Not Applicable"

- Very Dissatisfied
- Dissatisfied
- Neutral
- Satisfied
- Very Satisfied
- Not Applicable

Previous Next

TU/e Technische Universiteit Eindhoven University of Technology

Student Accommodation Preferences Survey

(Readonly)

Section 2

In this section you will be asked to compare criteria and location attributes

According to your own perception, you have to select the option that best suits the importance of each comparisson. For example:

	Very strong	Strong	Slight	Equal	Slight	Strong	Very strong	
Distance to Closest Bus Stop	○	○	●	○	○	○	○	Distance to Nearest Main Road

In the previous example a comparisson between "Distance to closest bus stop" and "Distance to nearest main road" was made. It was assumed that it was slightly more important the distance to bus stop than the distance to the main road

According to your perception, how the next amenities attributes compare?

	Very strong	Strong	Slight	Equal	Slight	Strong	Very strong	
Distance to Closest Green Area	○	○	○	○	○	●	○	Distance to Nearest Supermarket
Distance to Nearest Sport Facility	●	○	○	○	○	○	○	Distance to Closest Green Area
Distance to Closest Green Area	●	○	○	○	○	○	○	Distance to Nearest Healthcare Center
Distance to City Center	●	○	○	○	○	○	○	Distance to Closest Green Area
Distance to Closest Green Area	○	○	○	○	○	●	○	Distance to Nearest University
Distance to Nearest Supermarket	●	○	○	○	○	○	○	Distance to Closest Sport Facility
Distance to Closest Healthcare Center	○	○	○	○	○	○	●	Distance to Nearest Supermarket
Distance to Nearest Supermarket	●	○	○	○	○	○	○	Distance to City Center
Distance to Closest University	○	○	●	○	○	○	○	Distance to Nearest Supermarket
Distance to Nearest Sport Facility	●	○	○	○	○	○	○	Distance to Closest Healthcare Center
Distance to City Center	○	○	○	●	○	○	○	Distance to Nearest Sport Facility
Distance to Nearest Sport Facility	○	○	○	○	●	○	○	Distance to Closest University
Distance to Closest Healthcare Center	○	○	○	○	○	●	○	Distance to City Center
Distance to Nearest University	●	○	○	○	○	○	○	Distance to Closest Healthcare Center
Distance to Closest University	●	○	○	○	○	○	○	Distance to City Center
Neighborhood Population Density	●	○	○	○	○	○	○	Neighborhood Population Age

Previous Next

TU/e Technische Universiteit Eindhoven University of Technology

Student Accommodation Preferences Survey

(Readonly)

Section 2

In this section you will be asked to compare criteria and location attributes

In your opinion, how the following accesibility attributes compare?

	Very strong	Strong	Slight	Equal	Slight	Strong	Very strong	
Distance to Closest Bus Stop	●	○	○	○	○	○	○	Distance to Nearest Main Road
Distance to Nearest Train Station	○	○	●	○	○	○	○	Distance to Closest Bus Stop
Distance to Closest Bus Stop	●	○	○	○	○	○	○	Distance to Nearest Airport
Distance to Nearest Main Road	○	○	○	○	○	●	○	Distance to Closest Train Station
Distance to Closest Airport	○	○	○	○	○	○	●	Distance to Nearest Main Road
Distance to Nearest Train Station	●	○	○	○	○	○	○	Distance to Closest Airport

In your opinion, how the following criteria compare?

	Very strong	Strong	Slight	Equal	Slight	Strong	Very strong	
Accessibility	○	○	○	○	●	○	○	Amenities
Accessibility	●	○	○	○	○	○	○	Population
Population	○	○	○	○	○	○	●	Amenities

Previous Next

Student Accommodation Preferences Survey

(Readonly)

Section 3

In this section personal information will be requested

What is your age?

26

What is your gender?

- Man
- Woman

What is your nationality?

Mexican

In what of the following educational level are you currently enrolled?

- Bachelors
- Masters
- PhD
- Postdoc
- Other

Indicate the 4 digit ZIP code of your current accommodation

5612

Previous Next

Student Accommodation Preferences Survey

(Readonly)

This is the end of the survey

Thank your for your cooperation

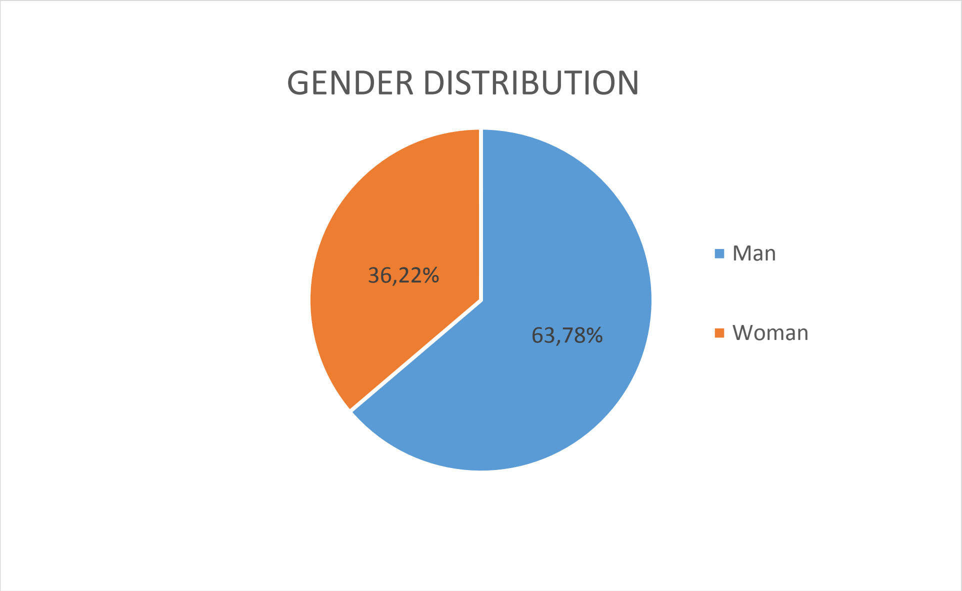
If there is any question regarding this questionnaire, do not hesitate in contacting me at s.n.corrales.silva@student.tue.nl

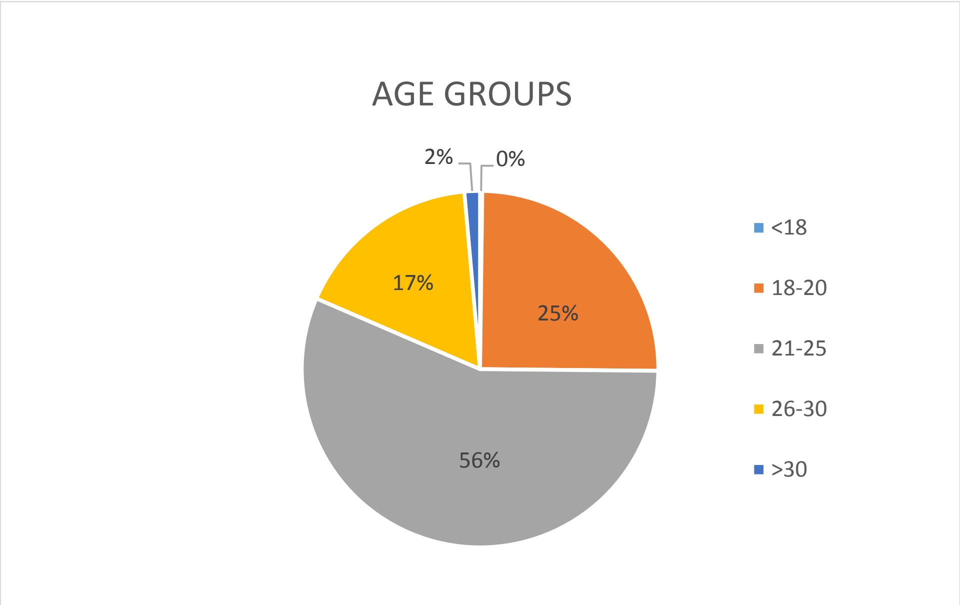
Sincerely,

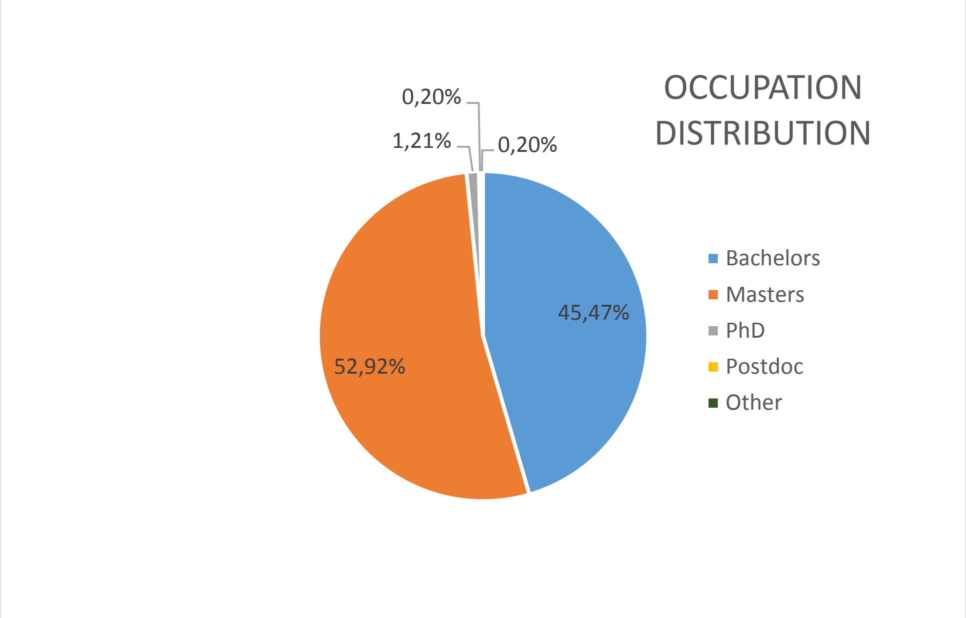
Shai Corrales

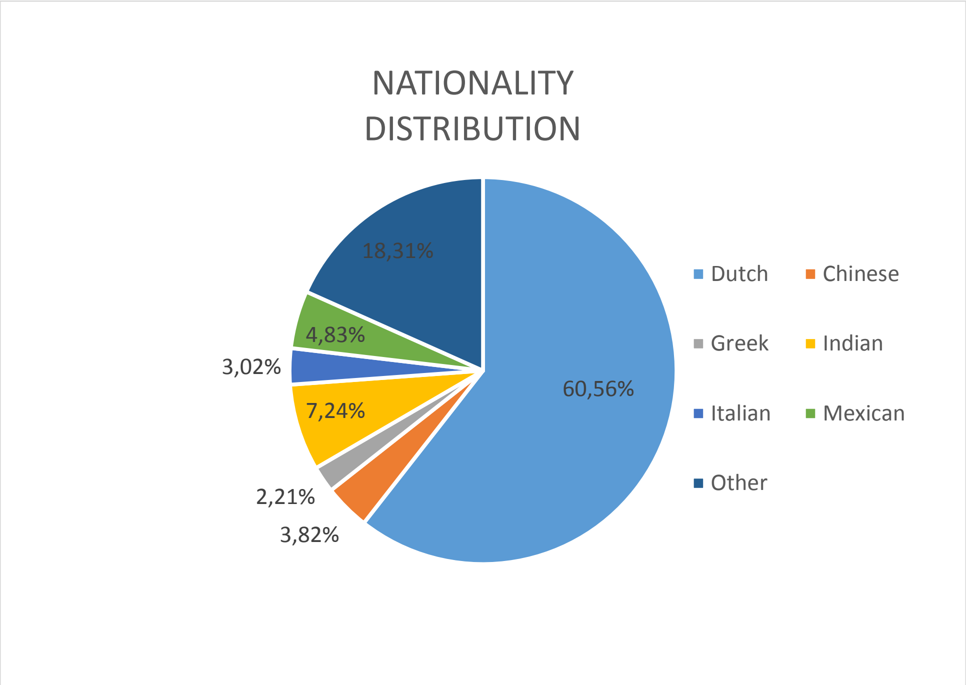
Previous Finish

A2 Original sample demographics

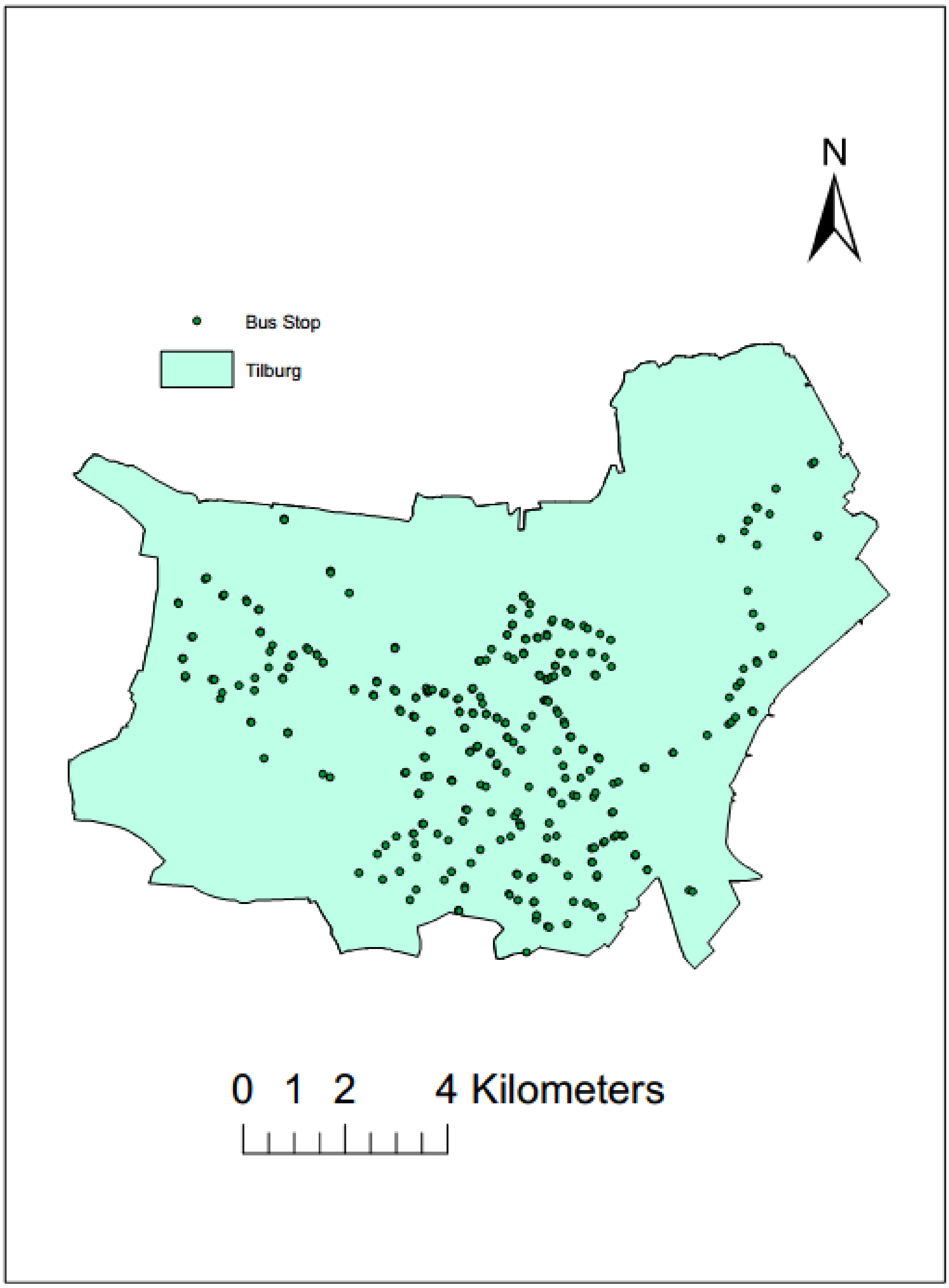


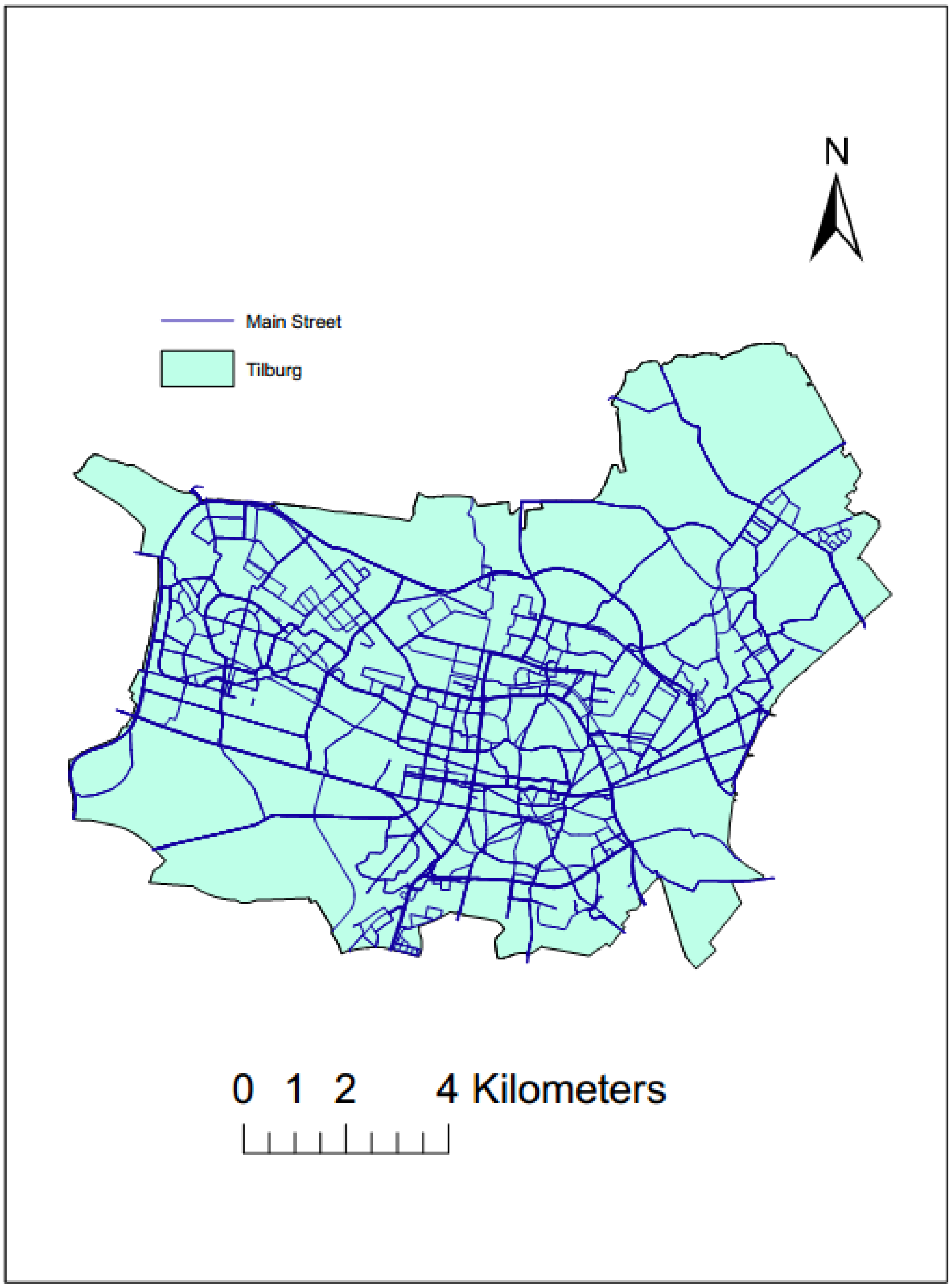


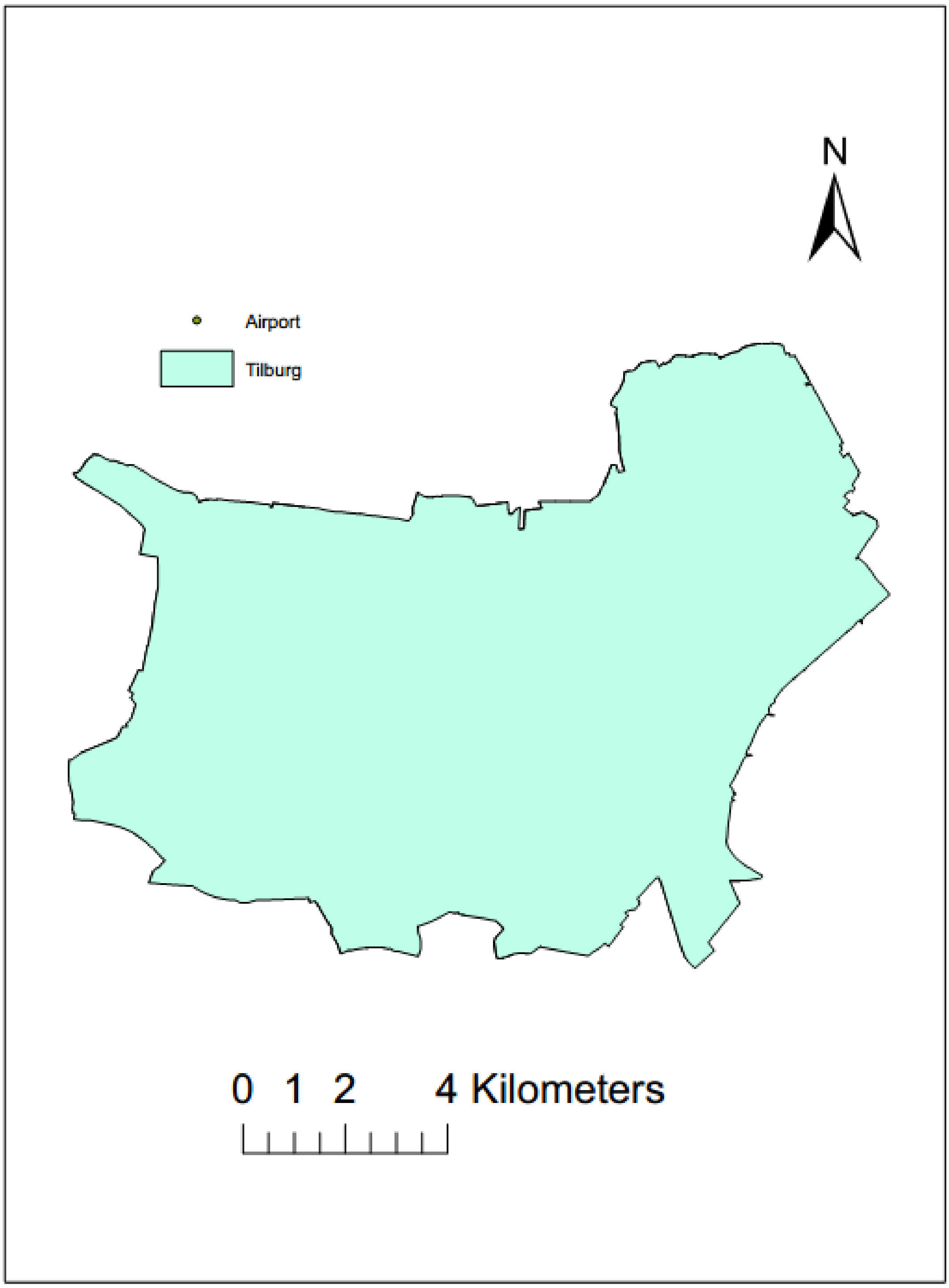

OCCUPATION DISTRIBUTION
0,20%
1,21%
0,20%
45,47%
52,92%
Bachelors
Masters
PhD
Postdoc
Other

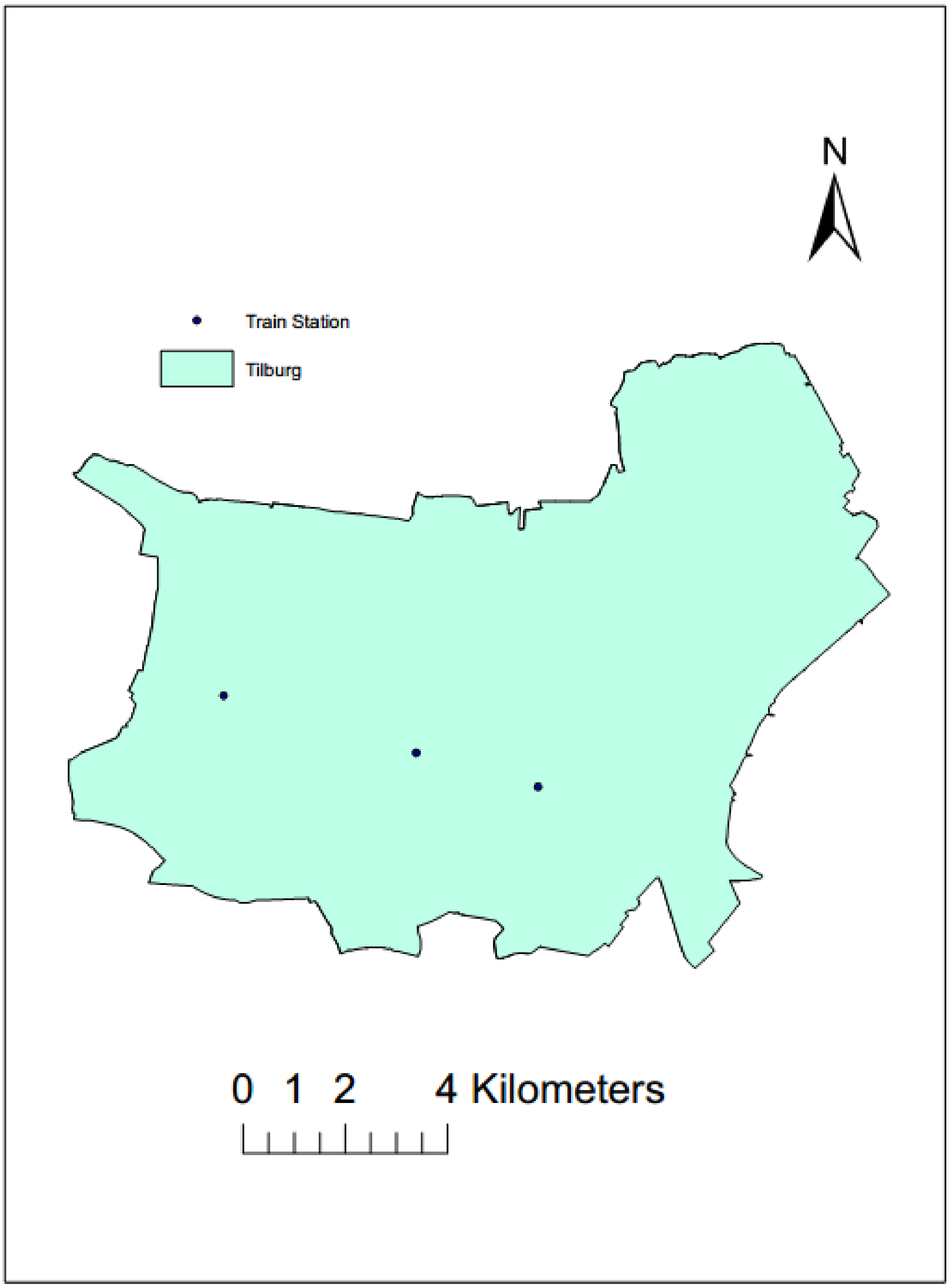

NATIONALITY DISTRIBUTION
18,31%
4,83%
3,02%
7,24%
2,21%
3,82%
60,56%
Dutch
Chinese
Greek
Indian
Italian
Mexican
Other

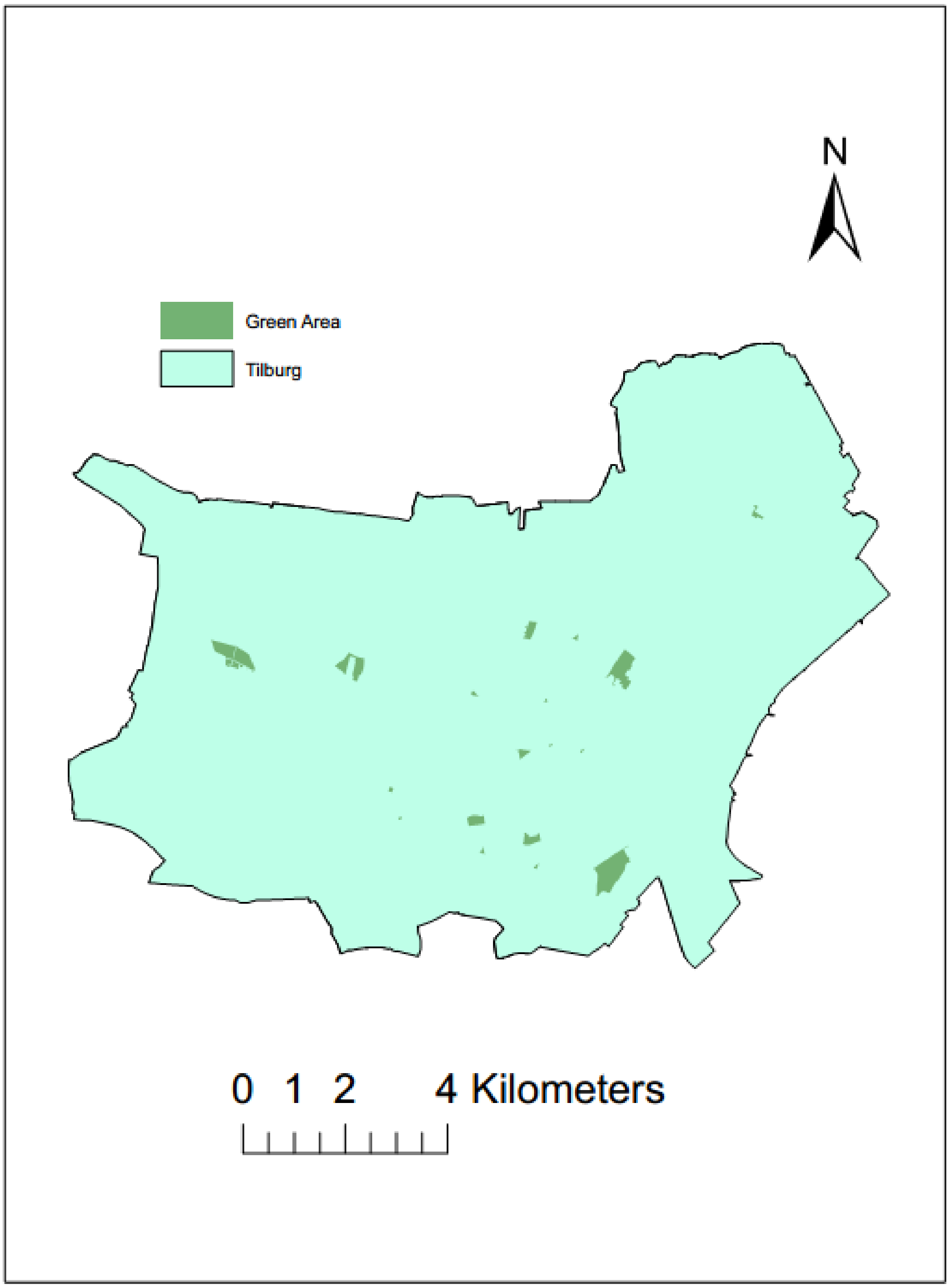
A3 Tilburg accessibility, amenities and population GIS files

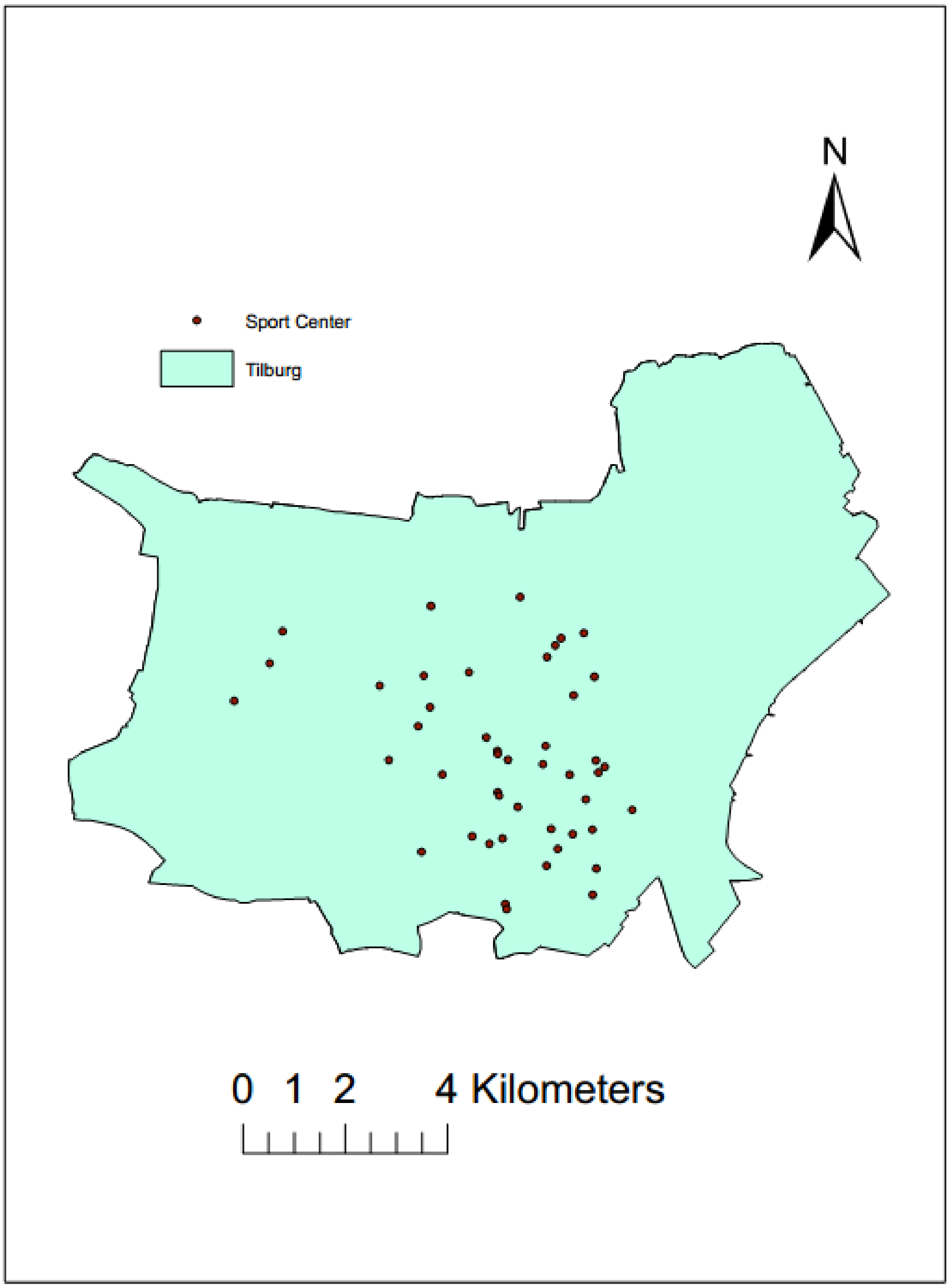


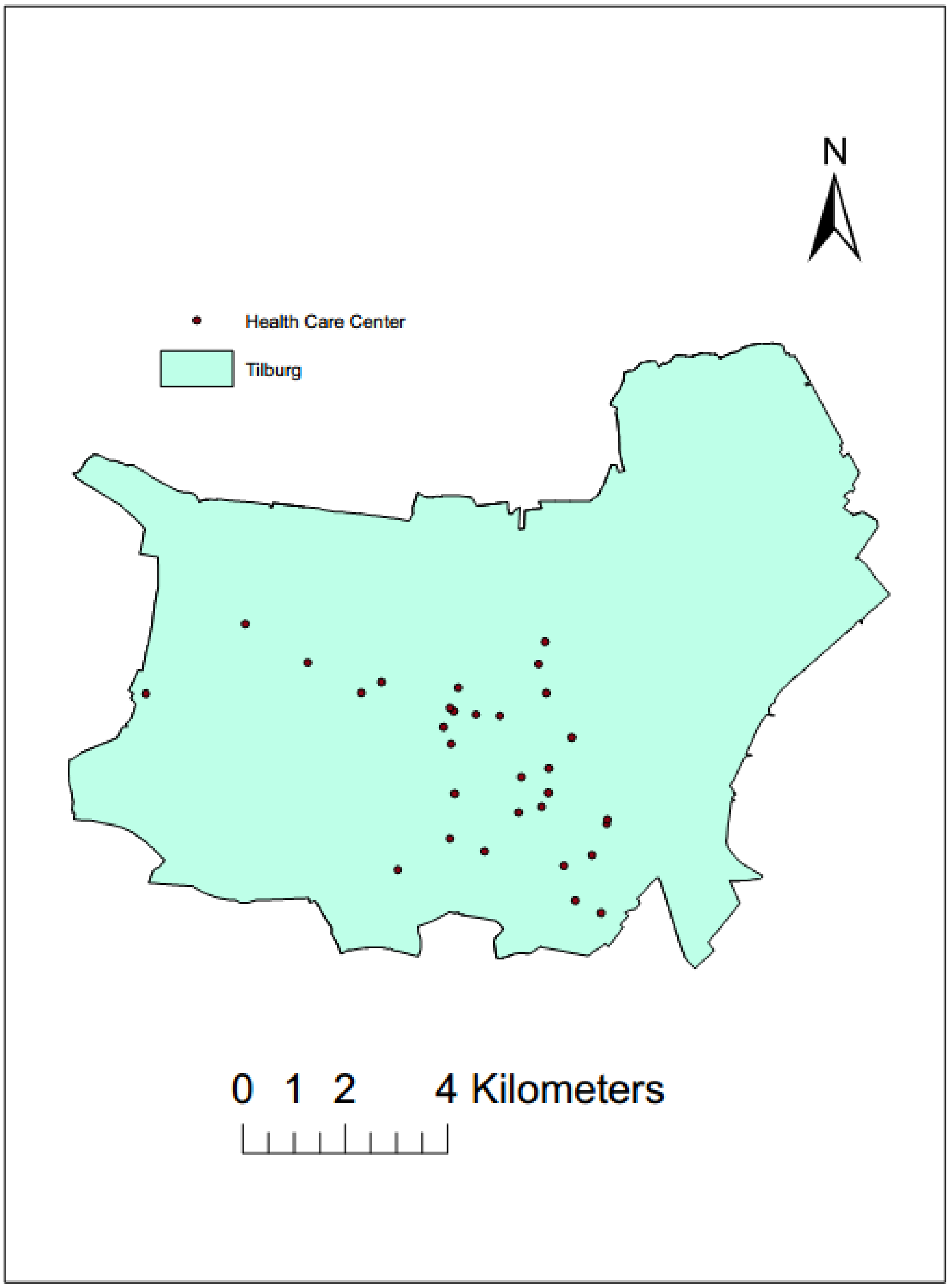

N
Main Street
Tilburg
0 1 2 4 Kilometers

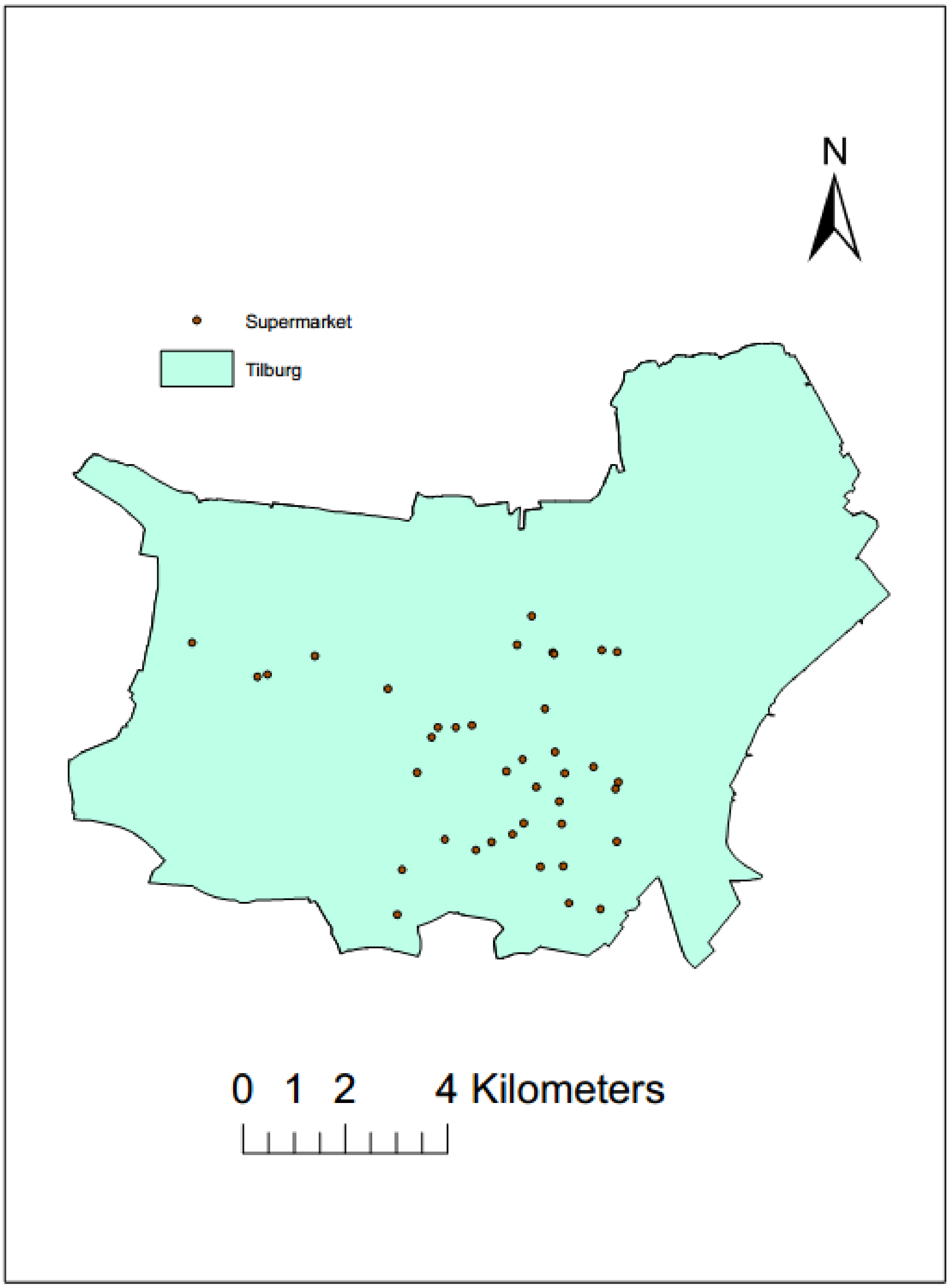

N
Airport
Tilburg
0 1 2 4 Kilometers

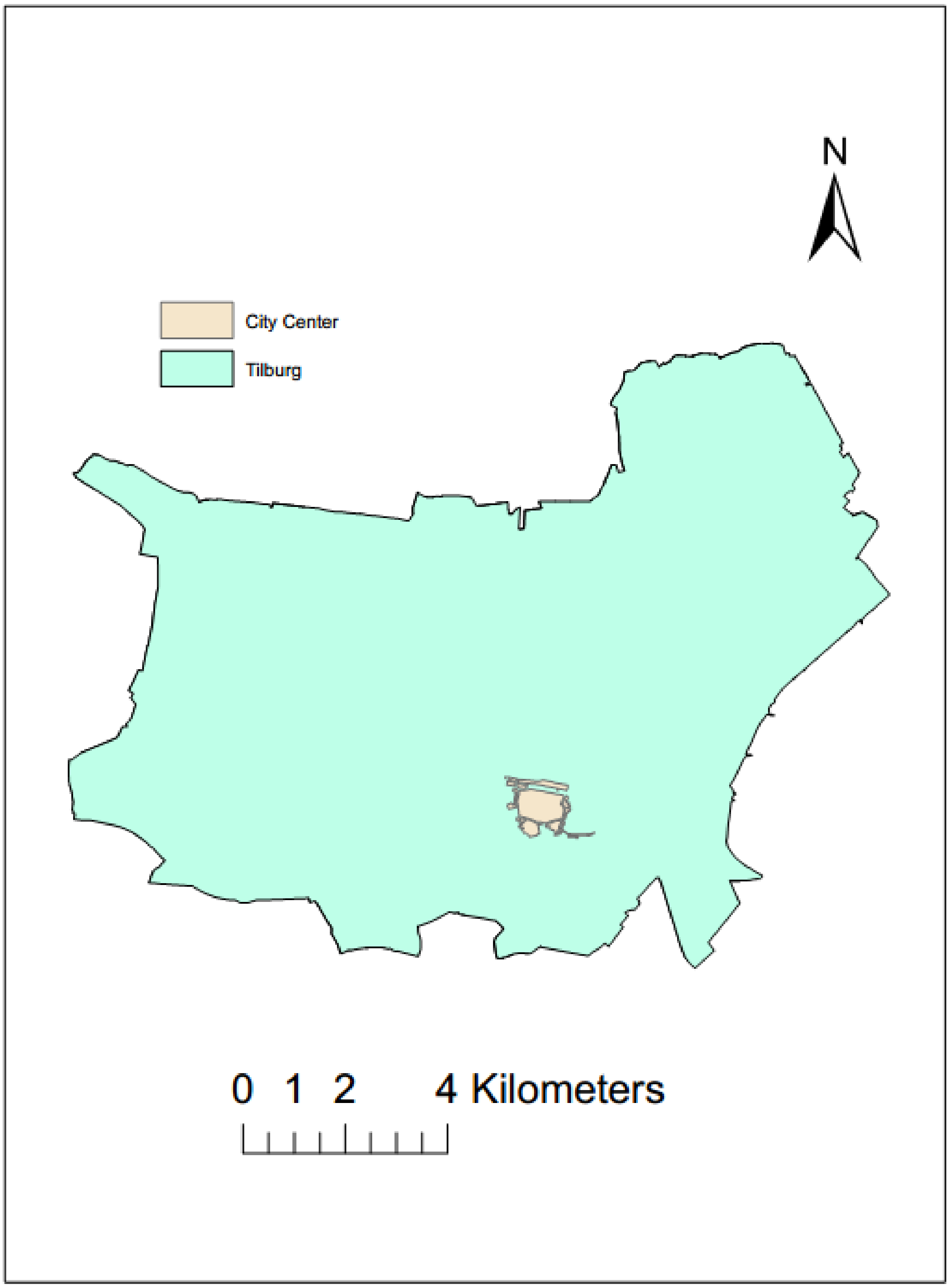

N
Train Station
Tilburg
0 1 2 4 Kilometers

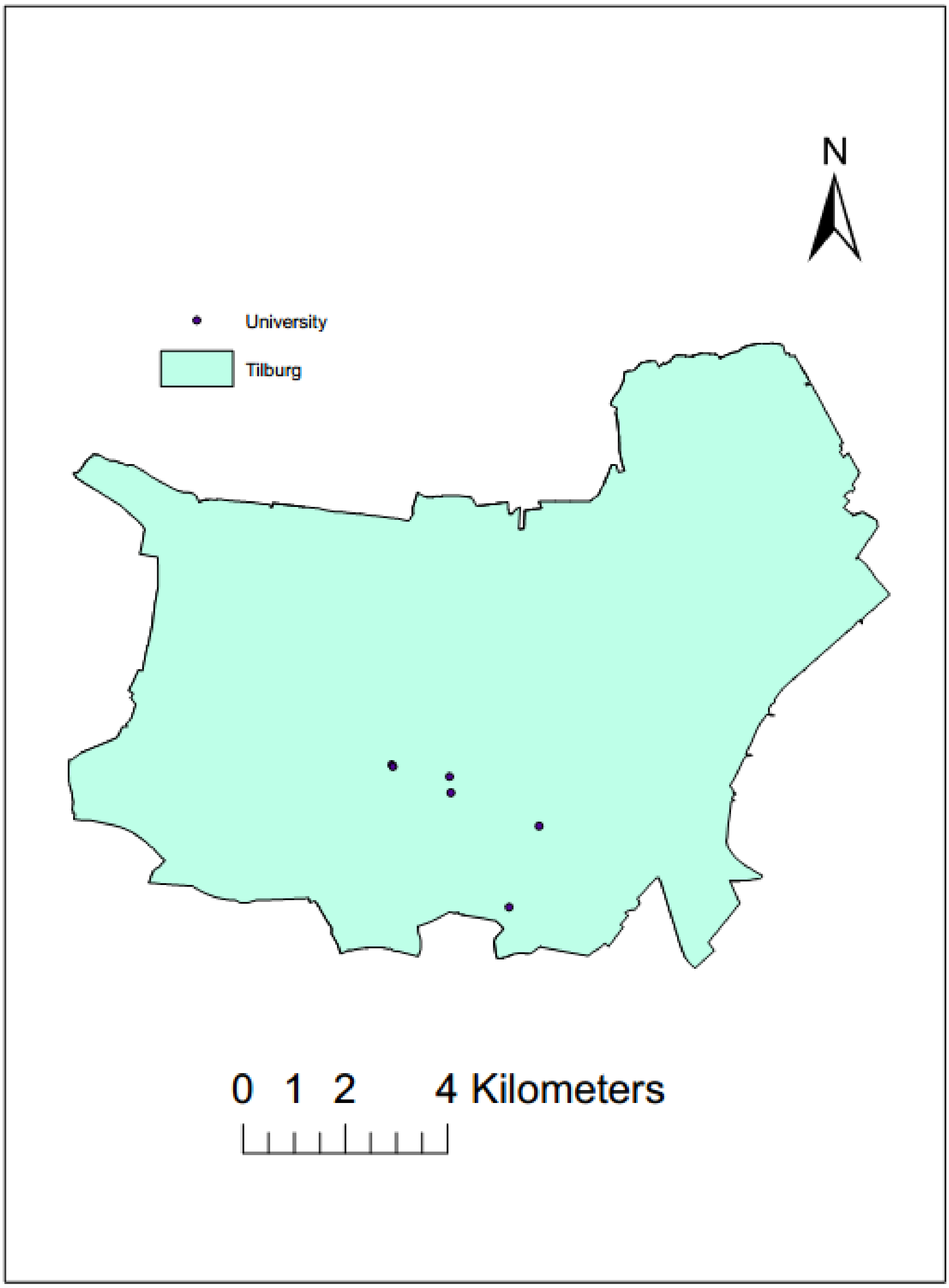

N
Green Area
Tilburg
0 1 2 4 Kilometers

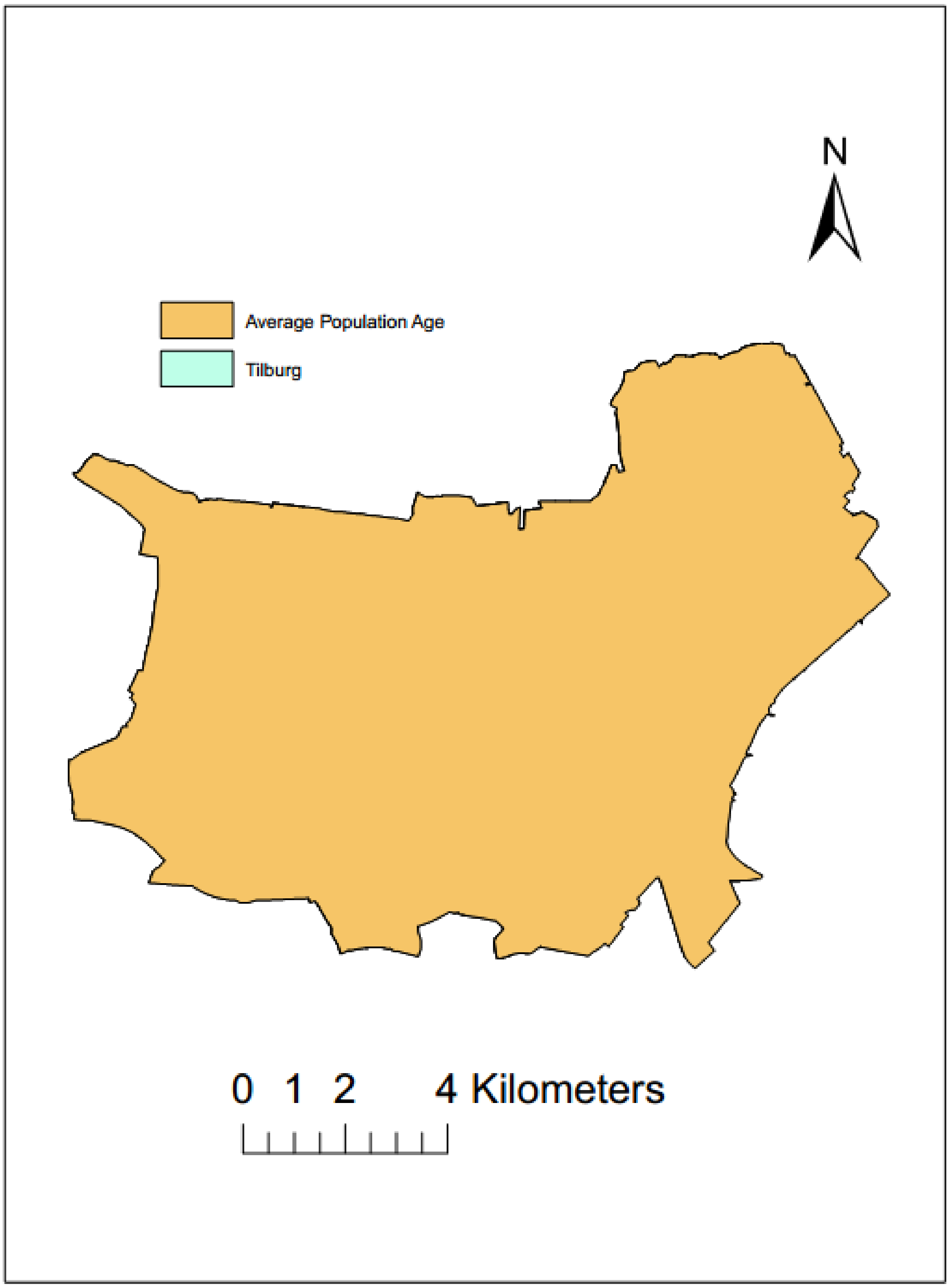

N
Sport Center
Tilburg
0 1 2 4 Kilometers

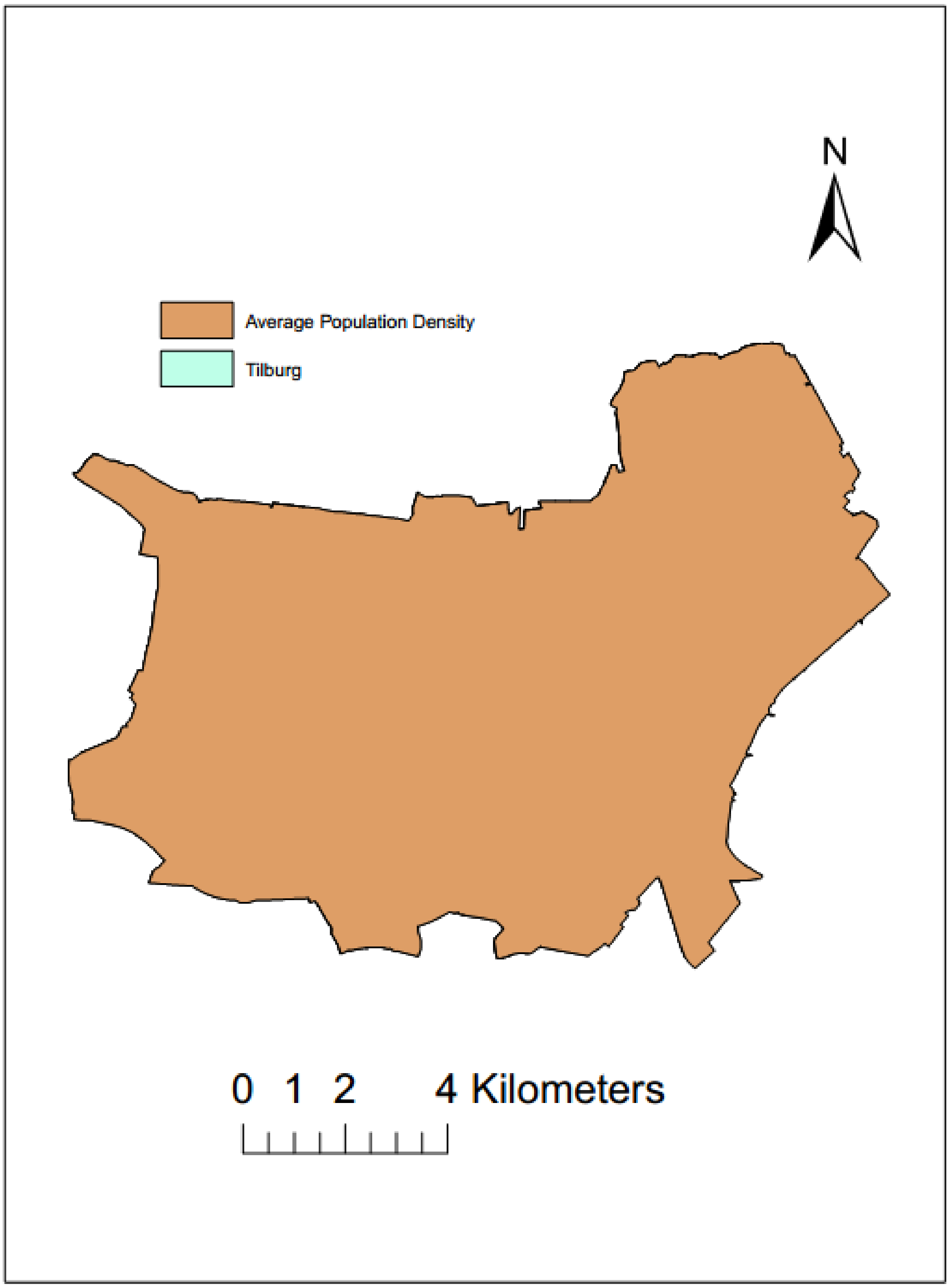

N
Health Care Center
Tilburg
0 1 2 4 Kilometers

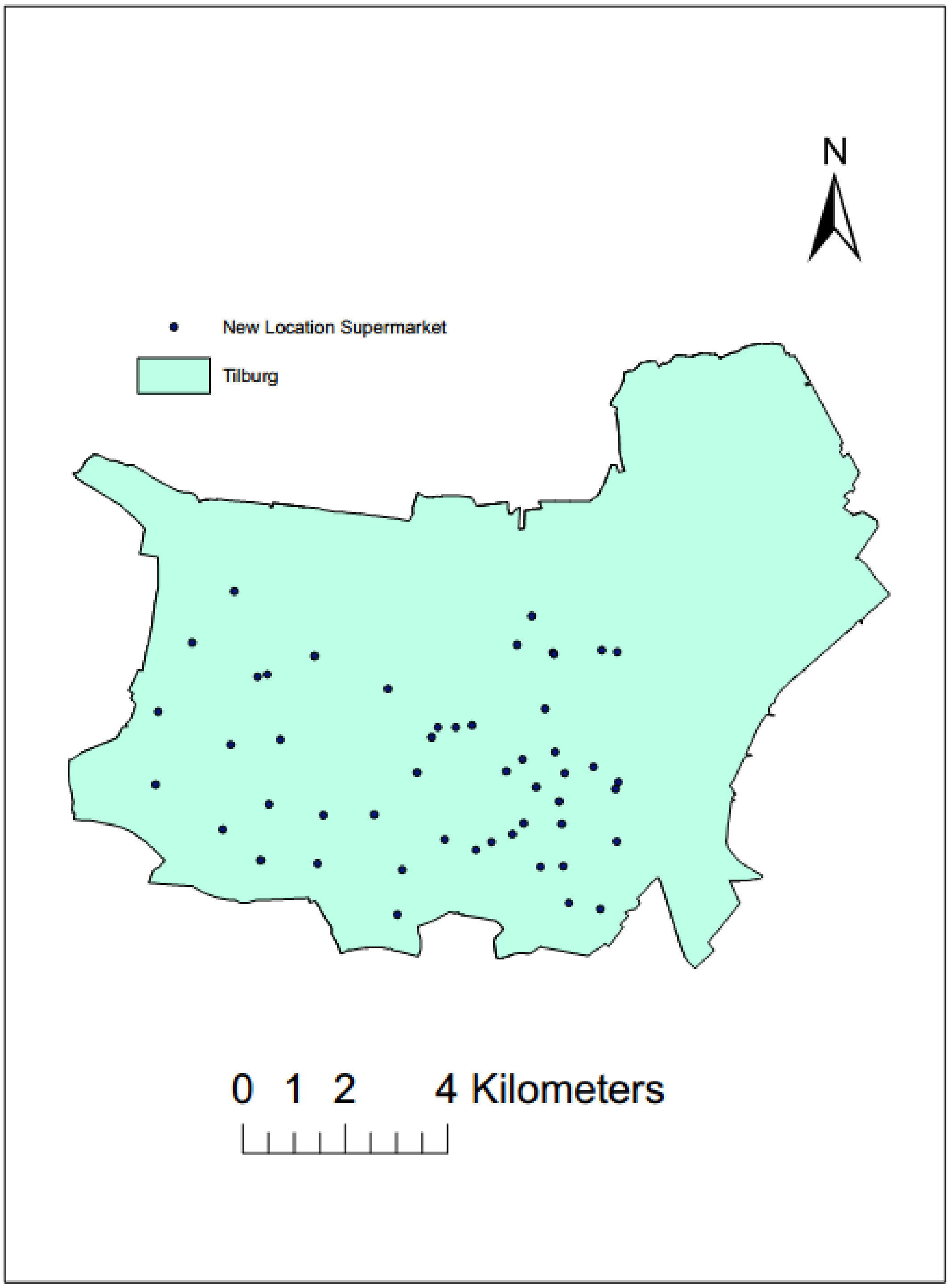

N
Supermarket
Tilburg
0 1 2 4 Kilometers

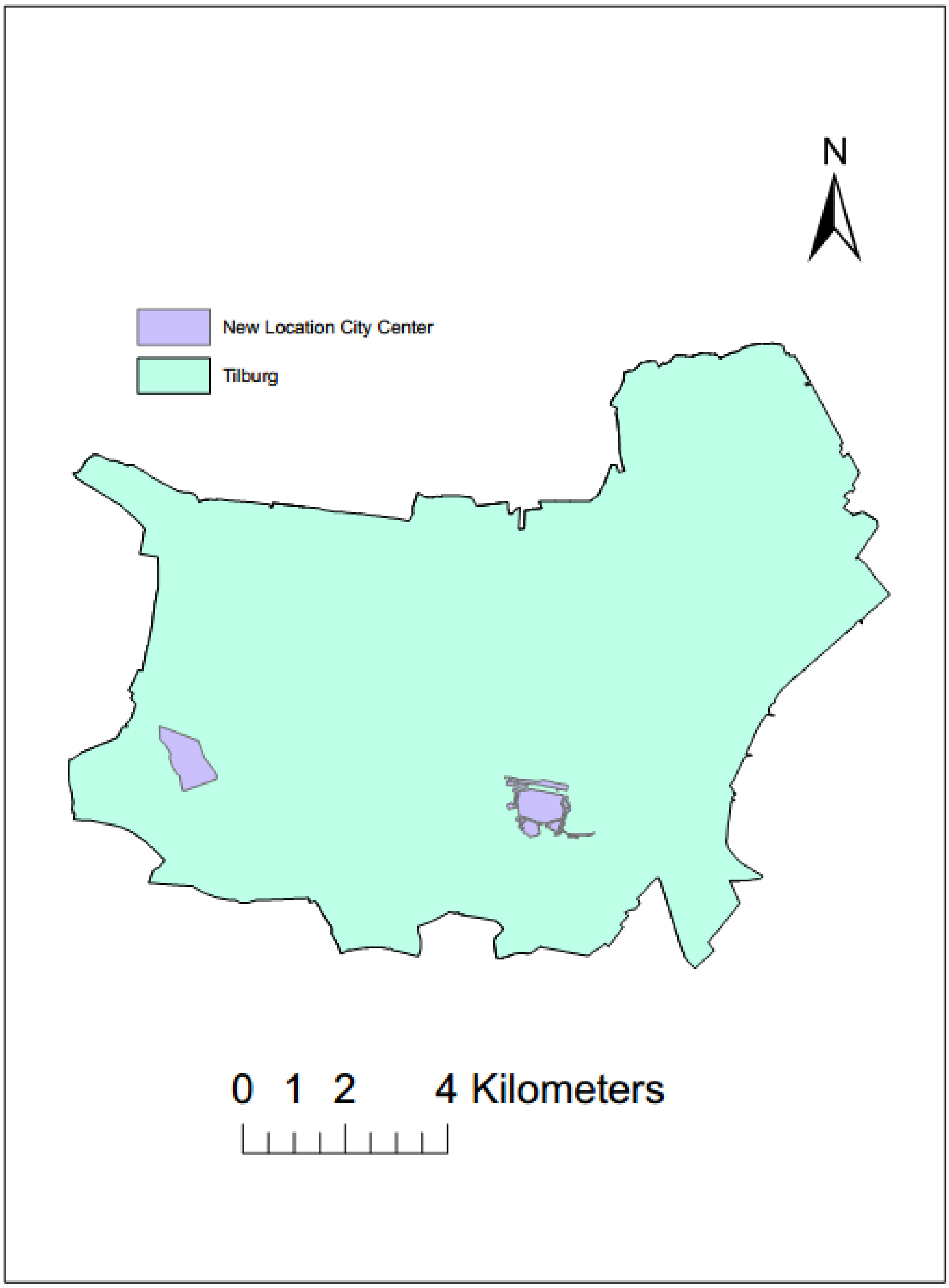

N
City Center
Tilburg
0 1 2 4 Kilometers

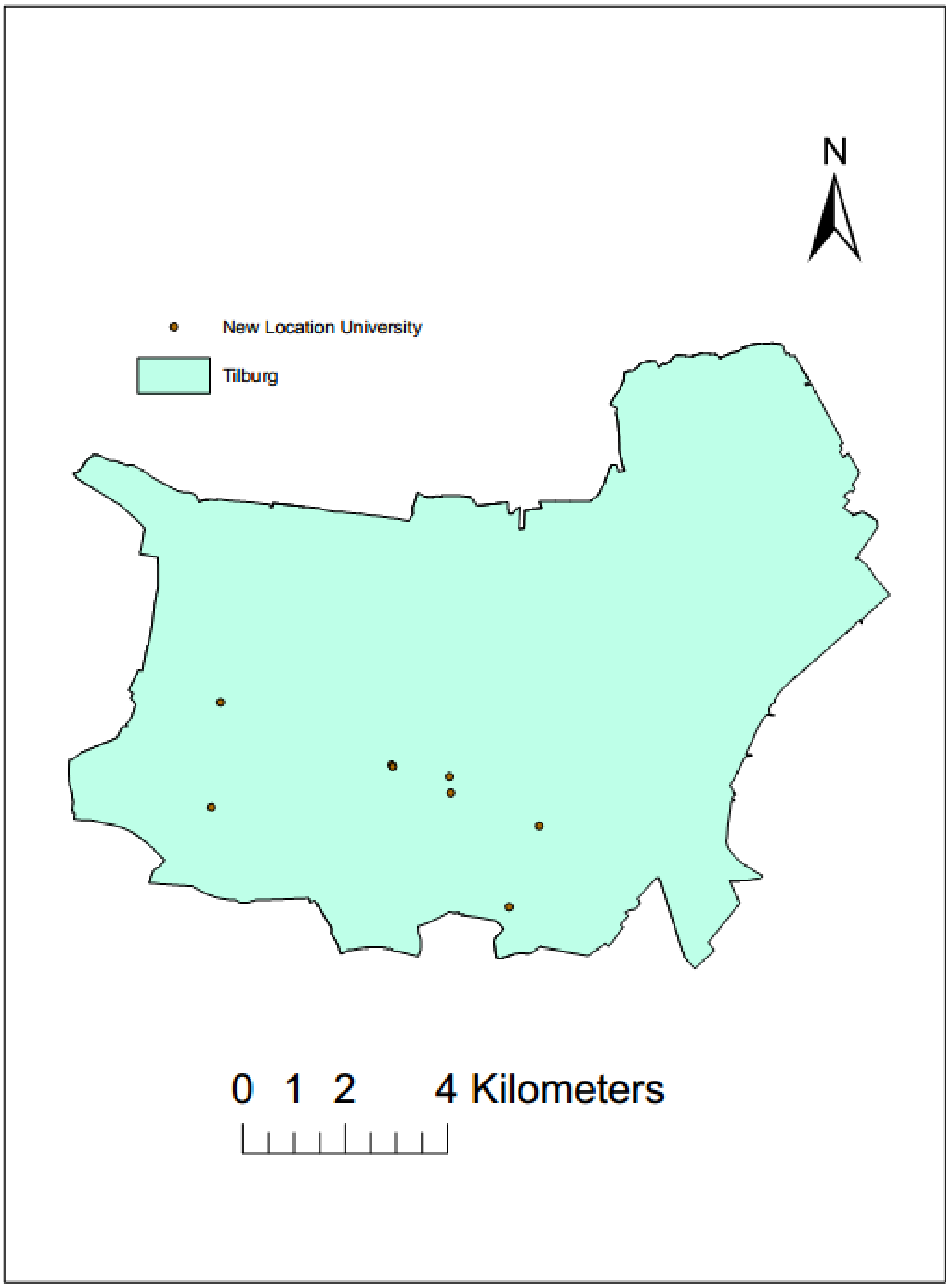

N
University
Tilburg
0 1 2 4 Kilometers


N
Average Population Age
Tilburg
0 1 2 4 Kilometers

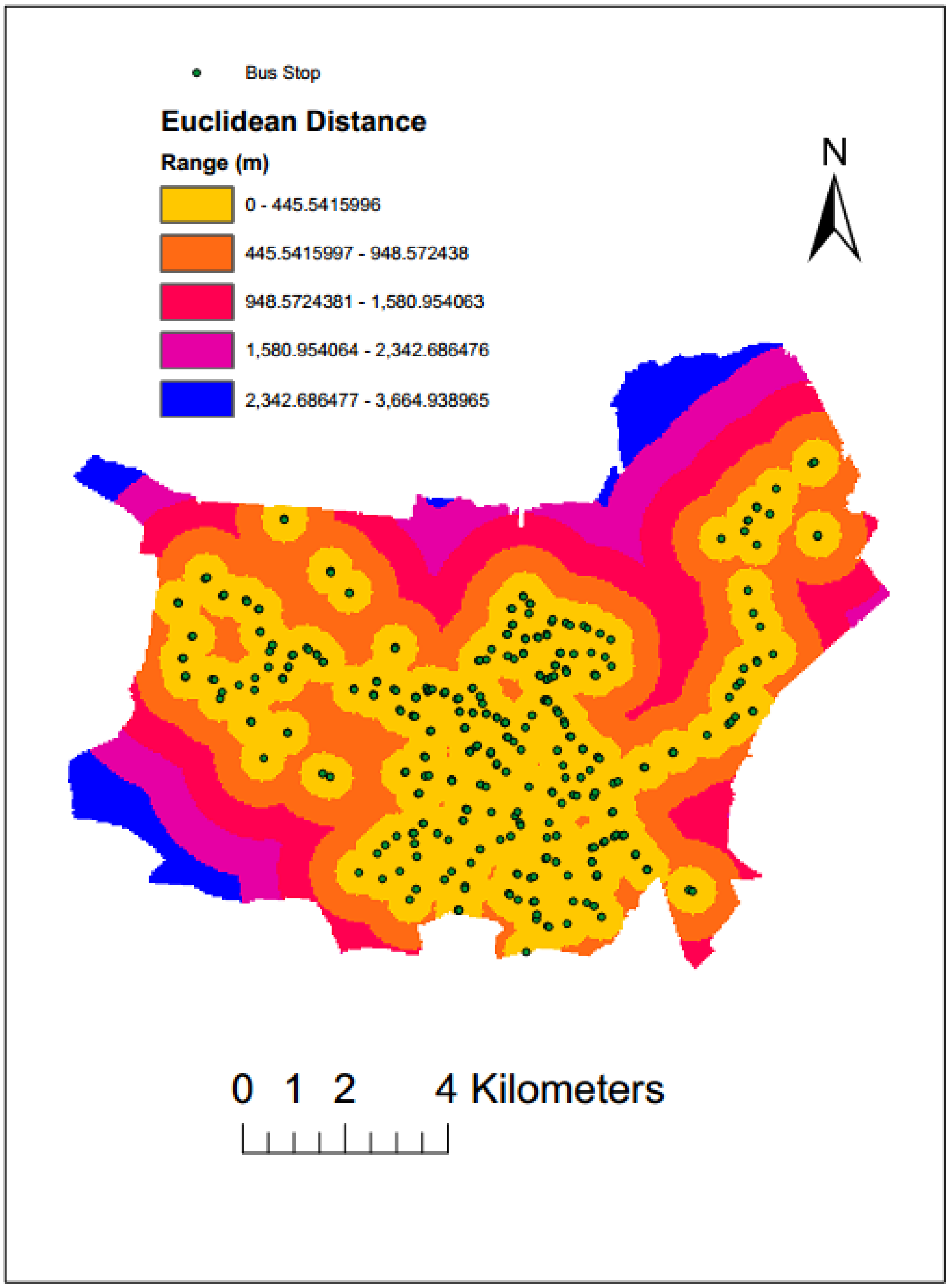

N
Average Population Density
Tilburg
0 1 2 4 Kilometers

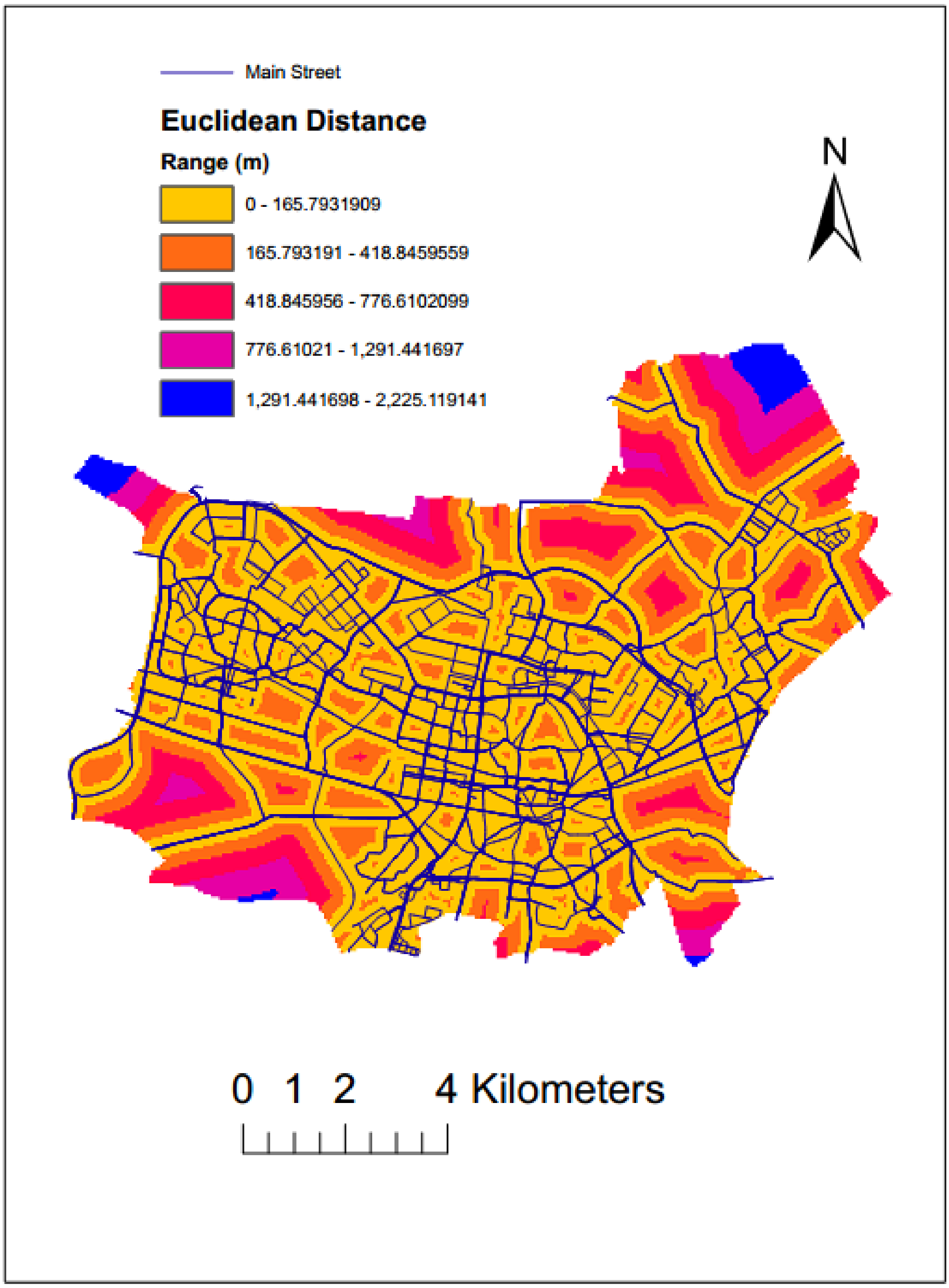

N
New Location Supermarket
Tilburg
0 1 2 4 Kilometers

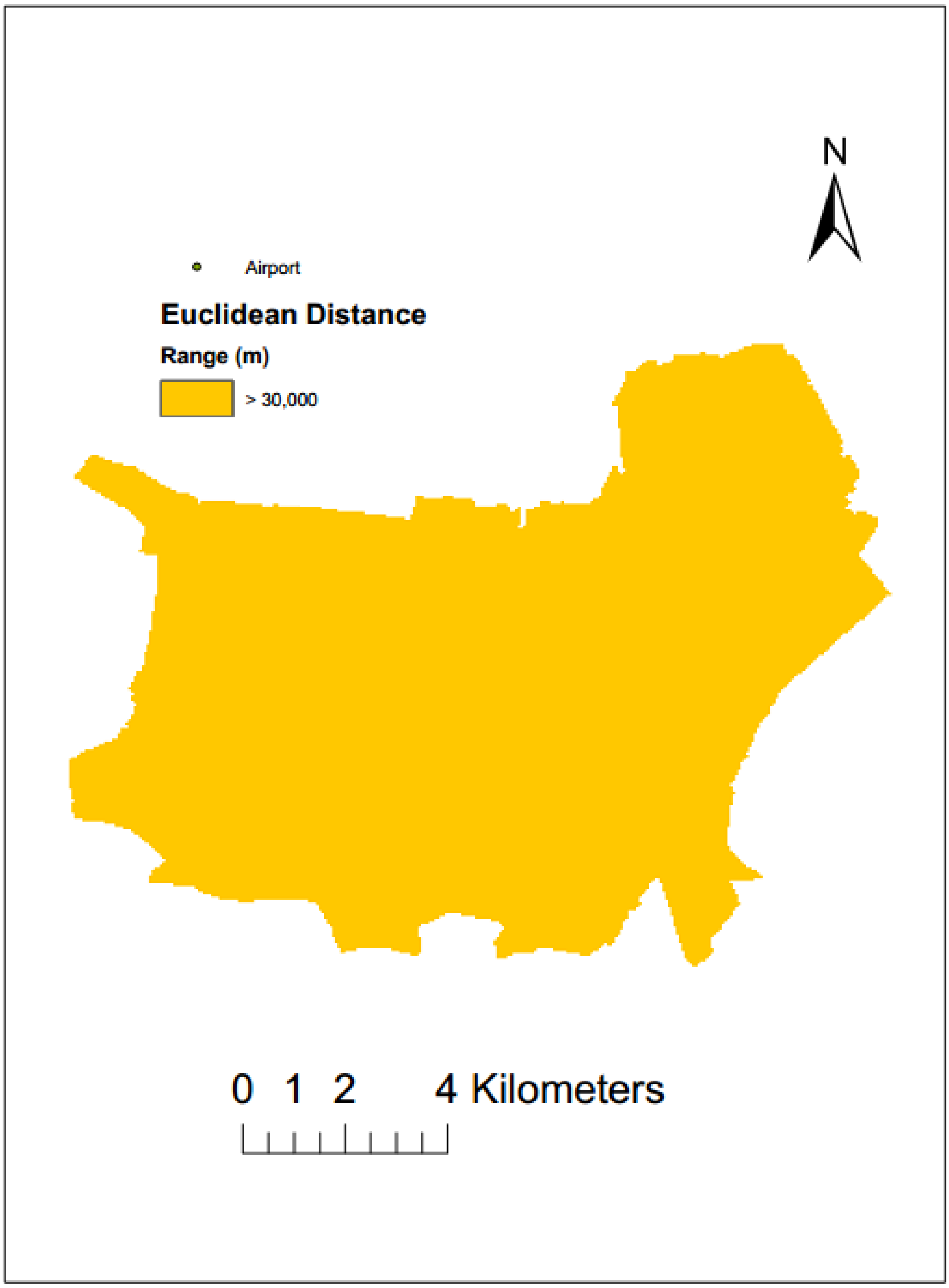

N
New Location City Center
Tilburg
0 1 2 4 Kilometers

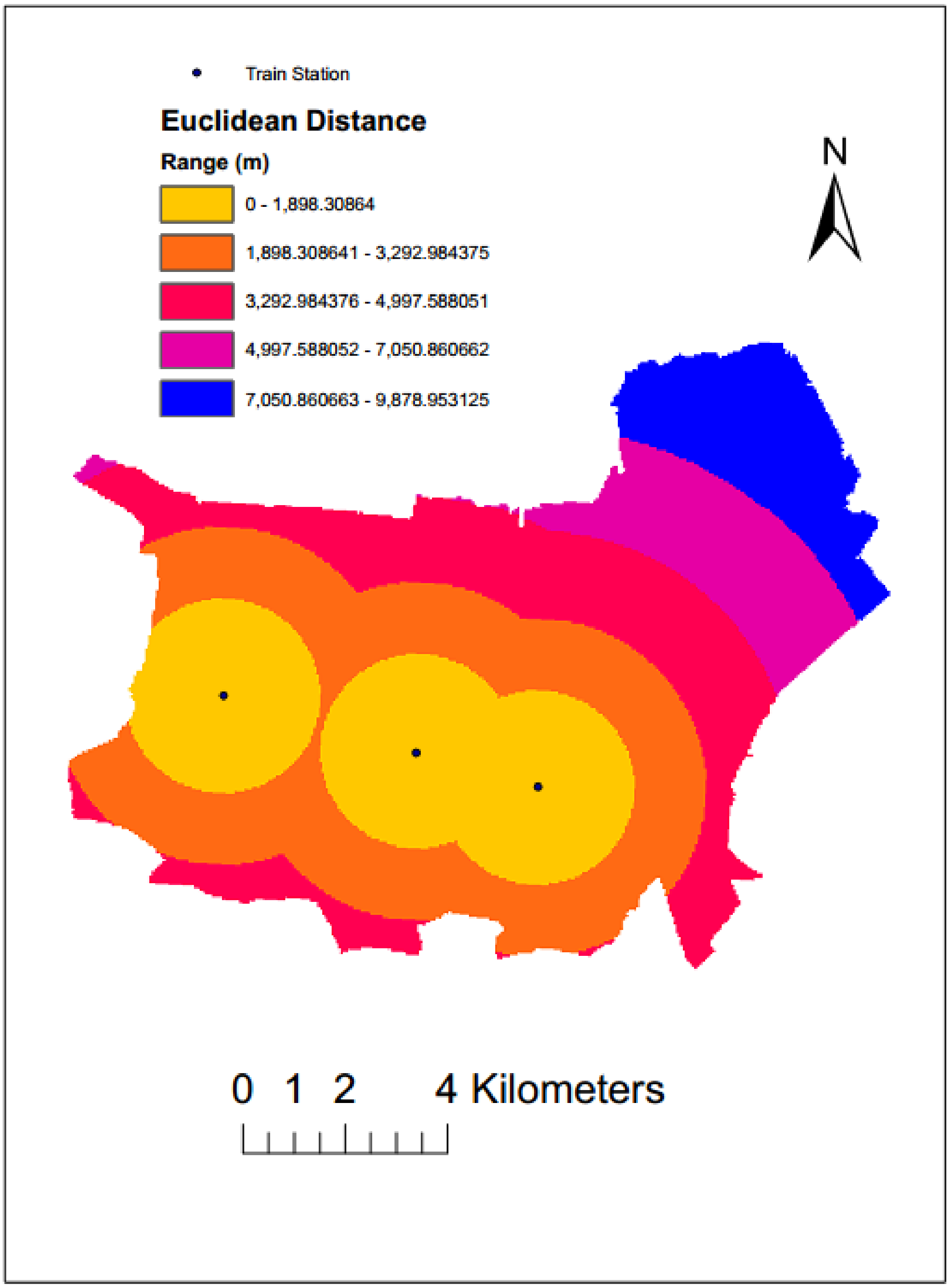

N
New Location University
Tilburg
0 1 2 4 Kilometers

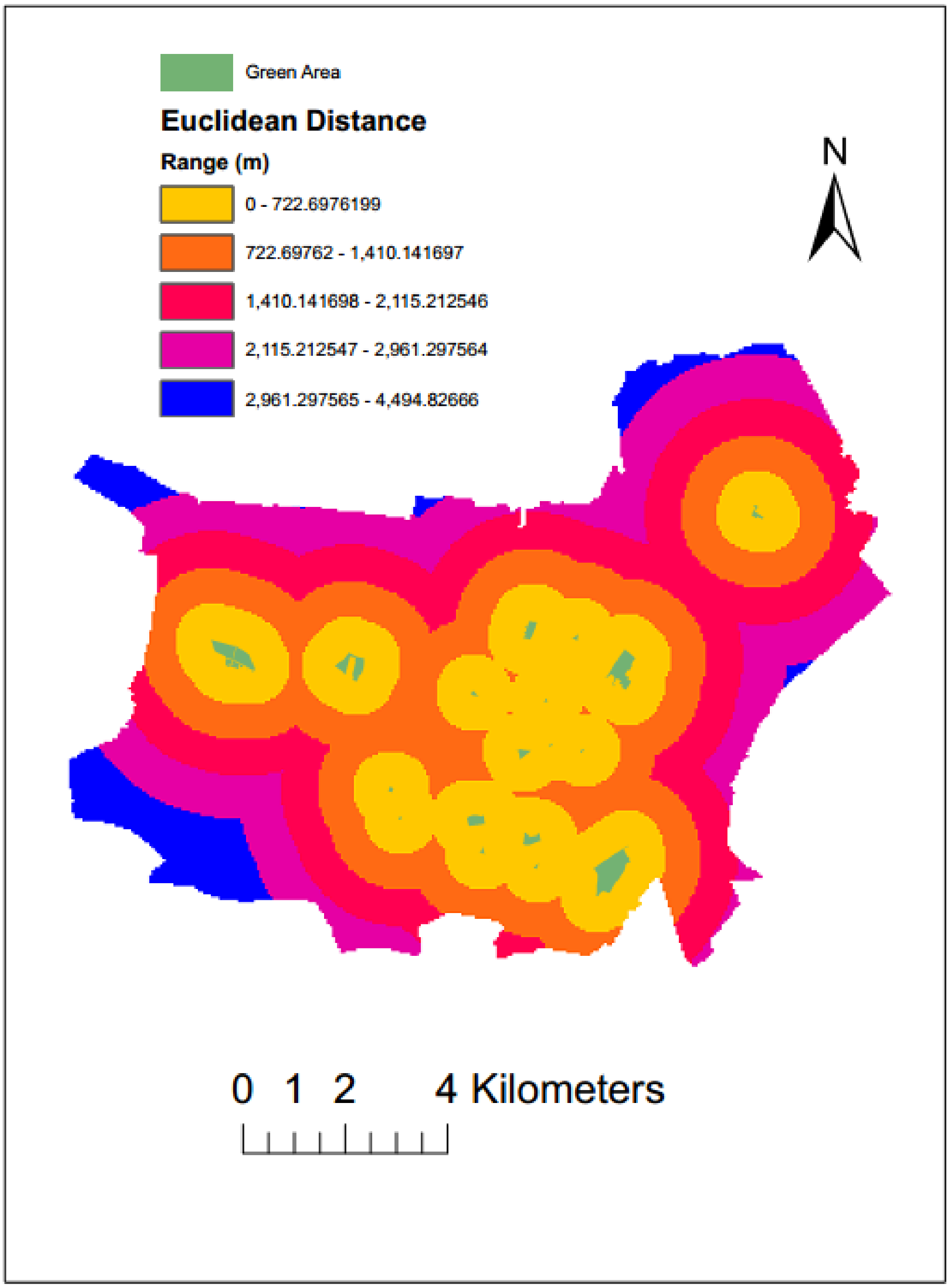
A4 Euclidean Distances

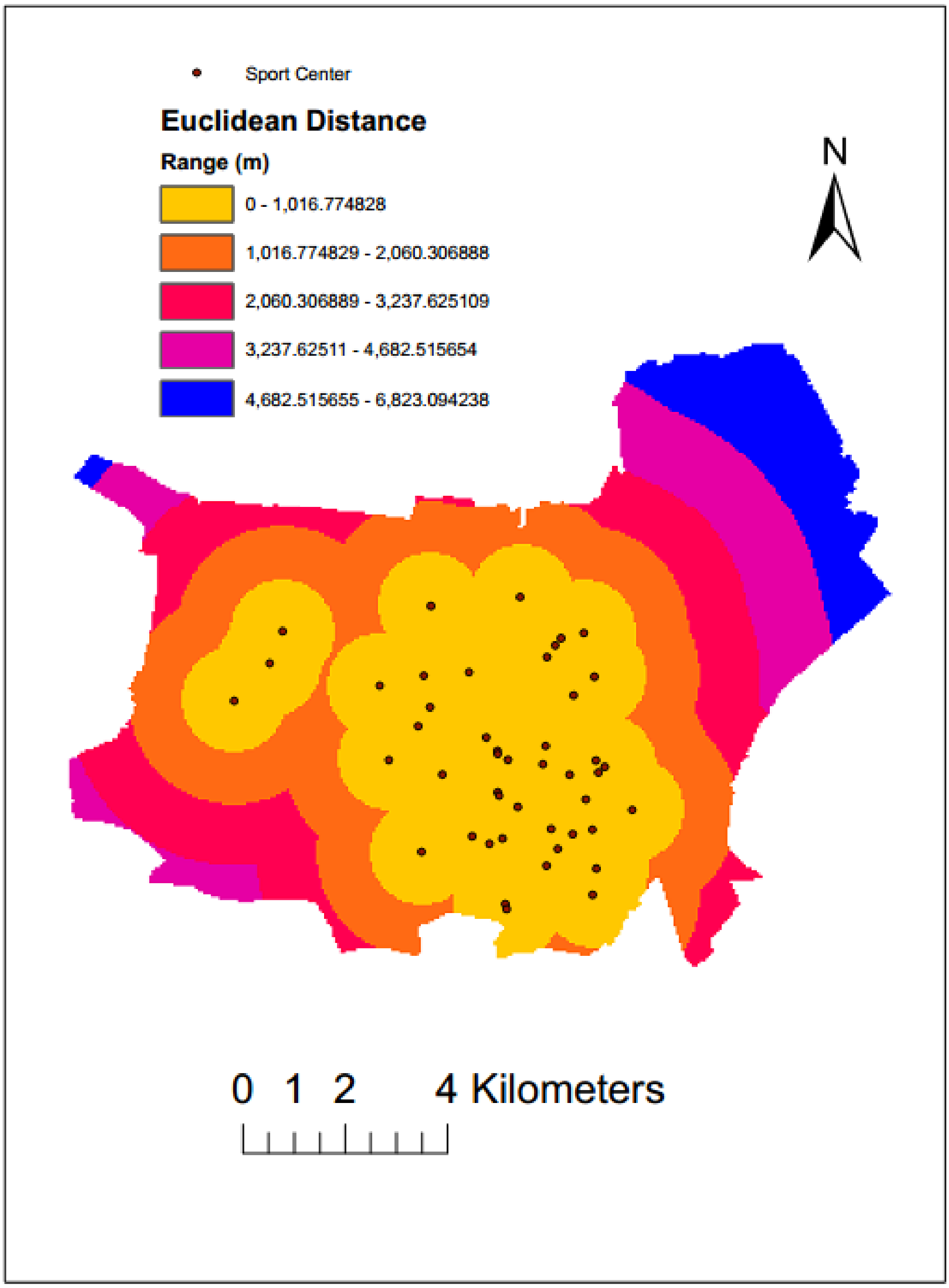


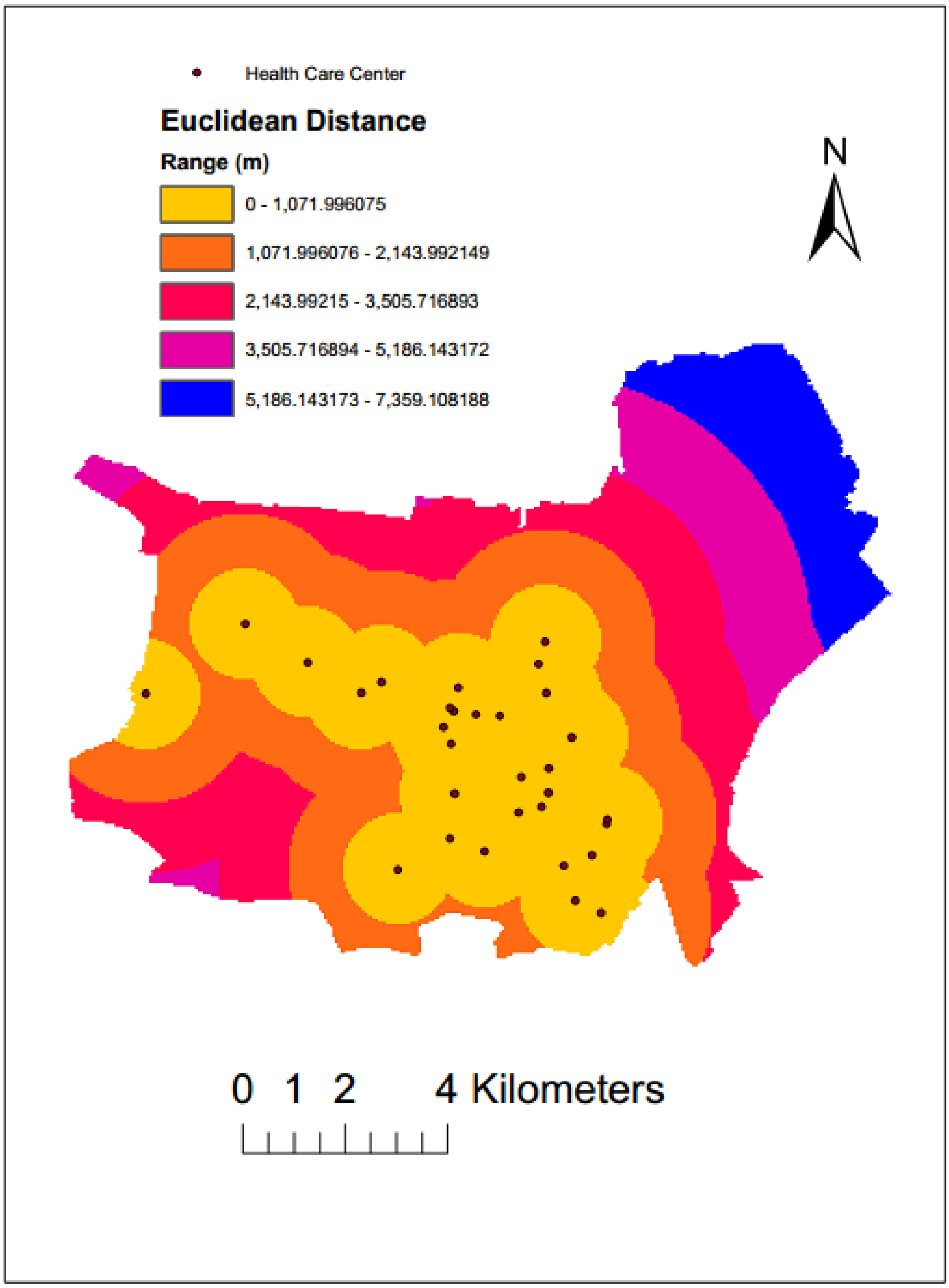

Main Street
Euclidean Distance
Range (m)
0 - 165.7931909
165.793191 - 418.8459559
418.845956 - 776.6102099
776.61021 - 1,291.441697
1,291.441698 - 2,225.119141
N
0 1 2 4 Kilometers

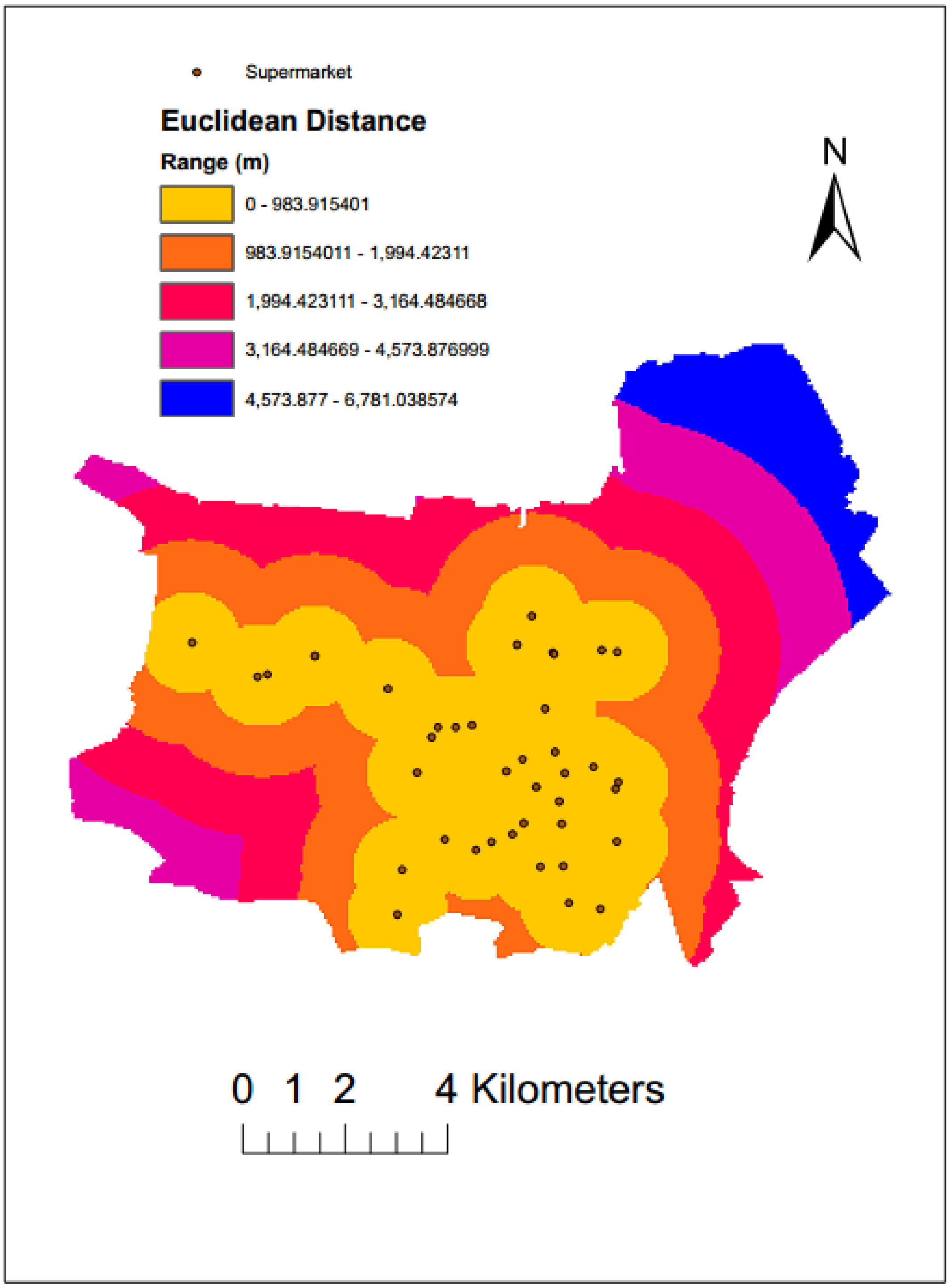

N
Airport
Euclidean Distance
Range (m)
> 30,000
0 1 2 4 Kilometers

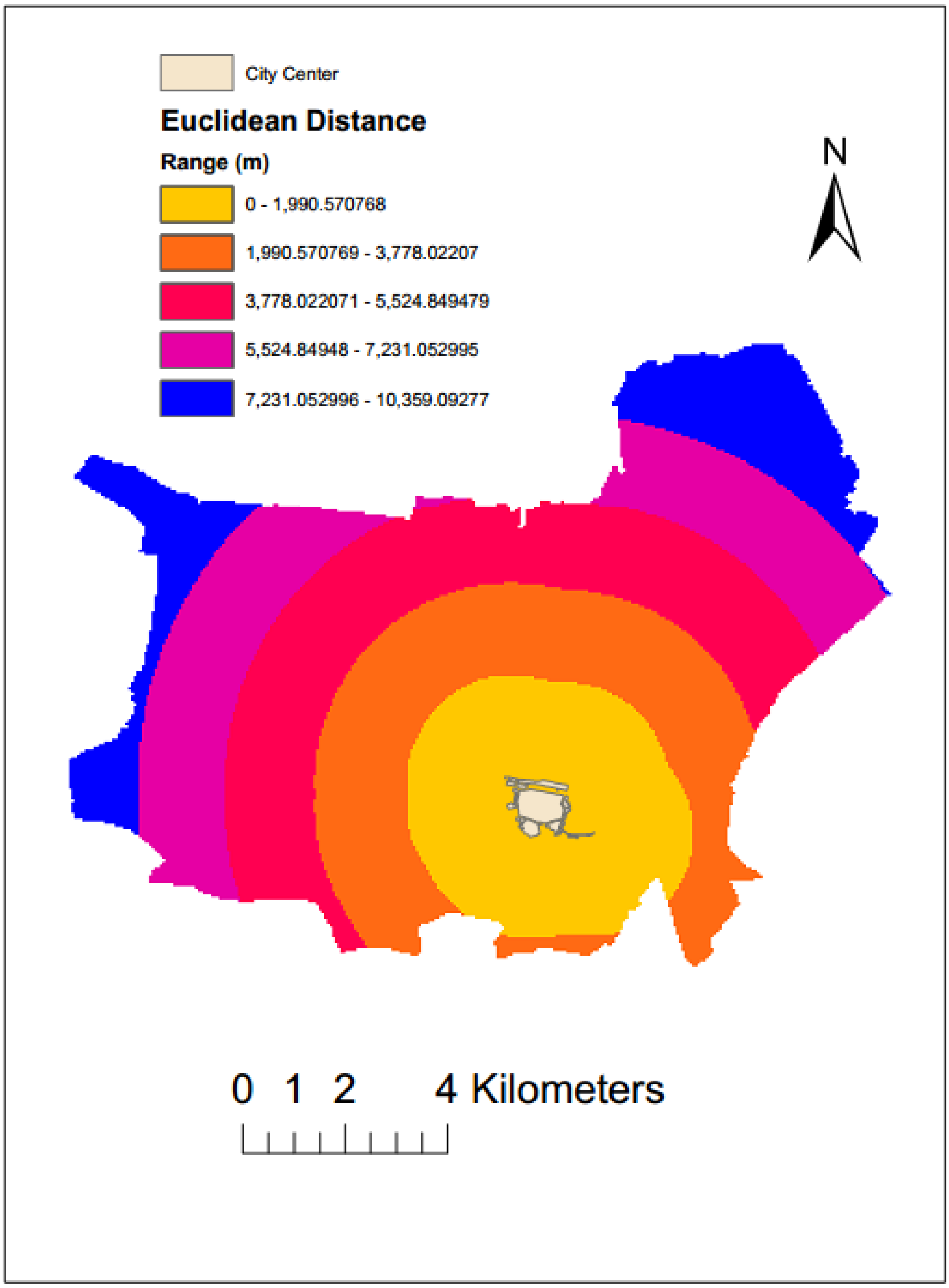

Train Station
Euclidean Distance
Range (m)
0 - 1,898.30864
1,898.308641 - 3,292.984375
3,292.984376 - 4,997.588051
4,997.588052 - 7,050.860662
7,050.860663 - 9,878.953125
N
0 1 2 4 Kilometers

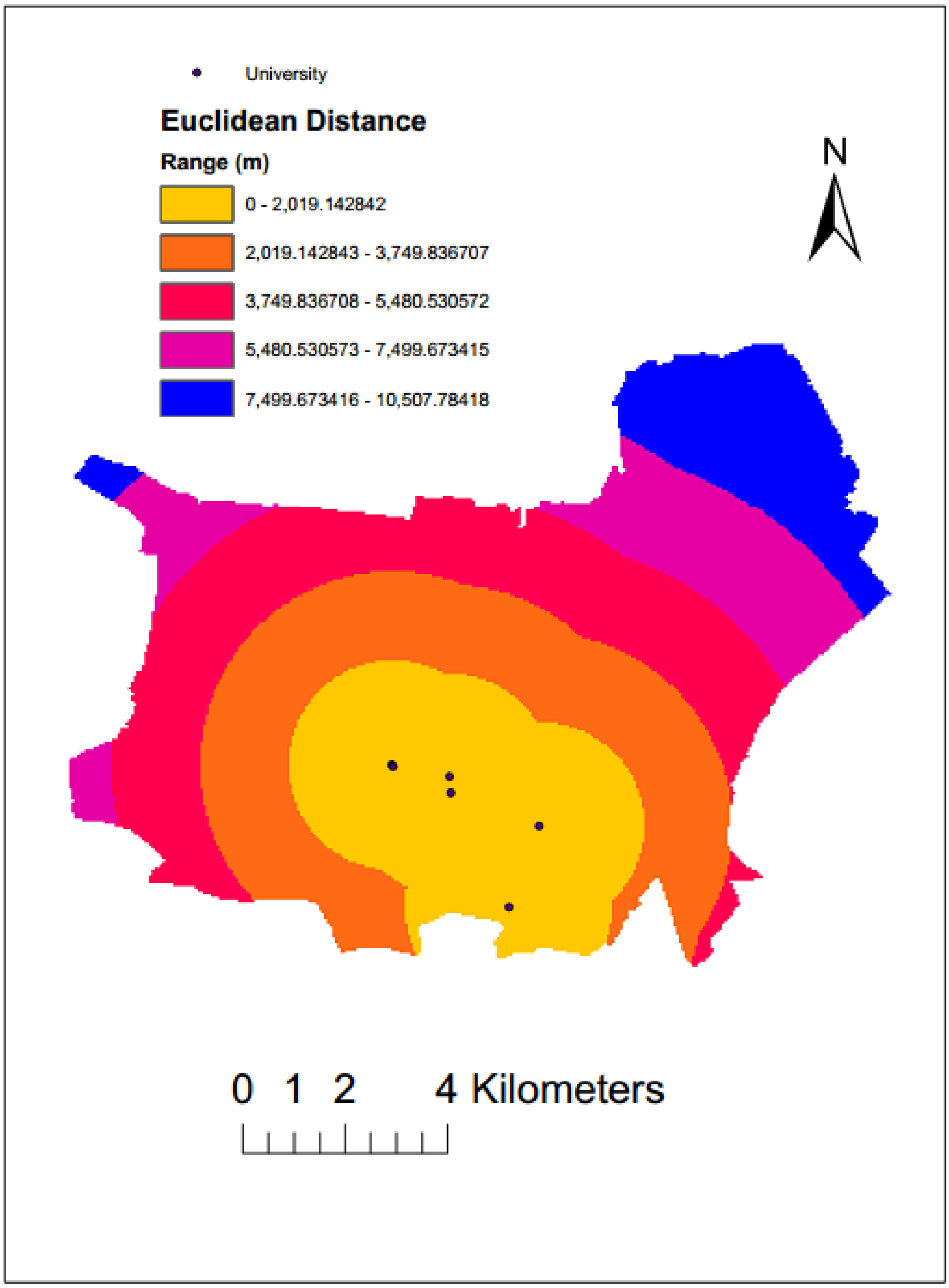

Green Area
Euclidean Distance
Range (m)
0 - 722.6976199
722.69762 - 1,410.141697
1,410.141698 - 2,115.212546
2,115.212547 - 2,961.297564
2,961.297565 - 4,494.82666
N
0 1 2 4 Kilometers

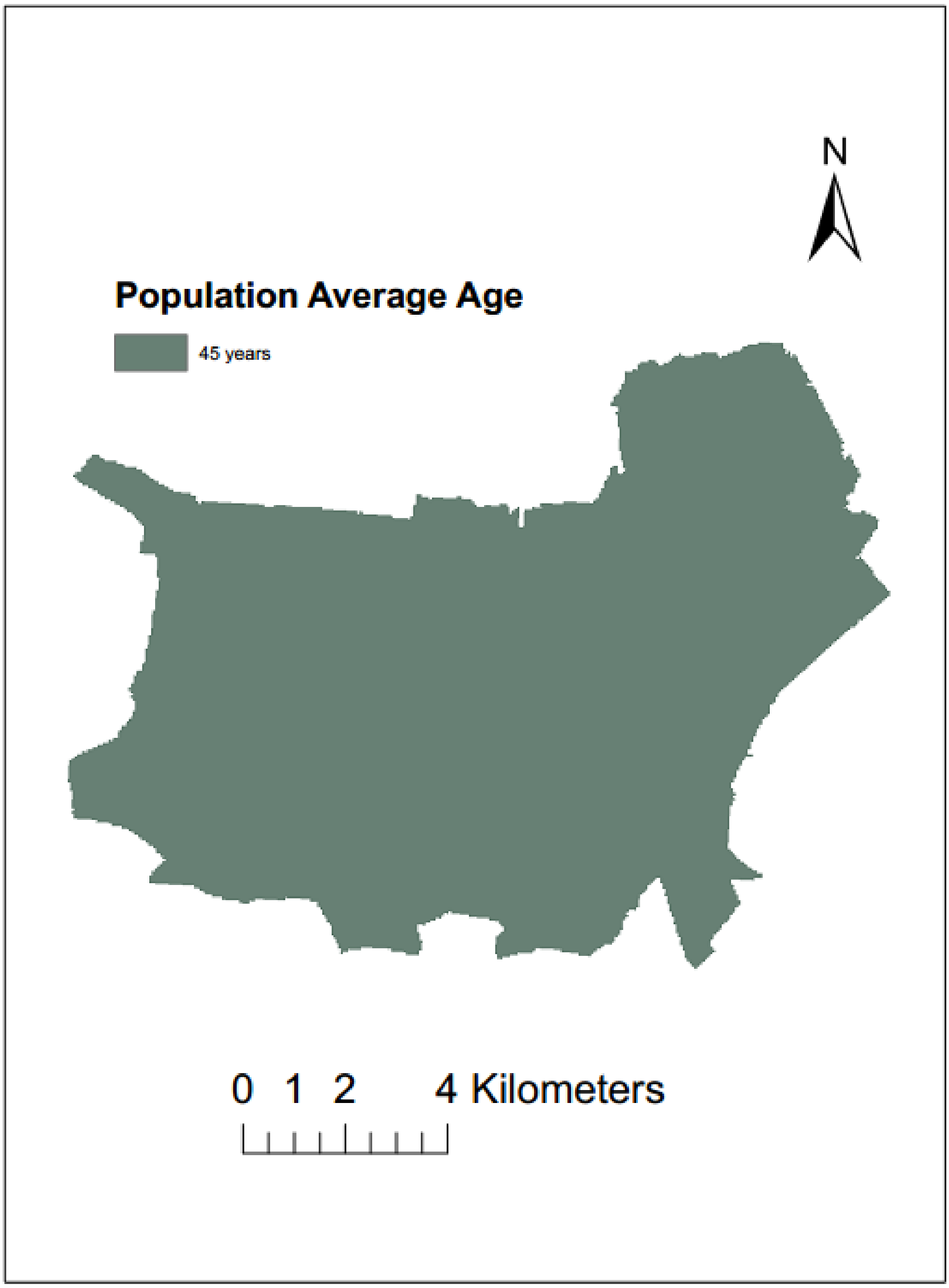

Sport Center
Euclidean Distance
Range (m)
0 - 1,016.774828
1,016.774829 - 2,060.306888
2,060.306889 - 3,237.625109
3,237.62511 - 4,682.515654
4,682.515655 - 6,823.094238
N
0 1 2 4 Kilometers

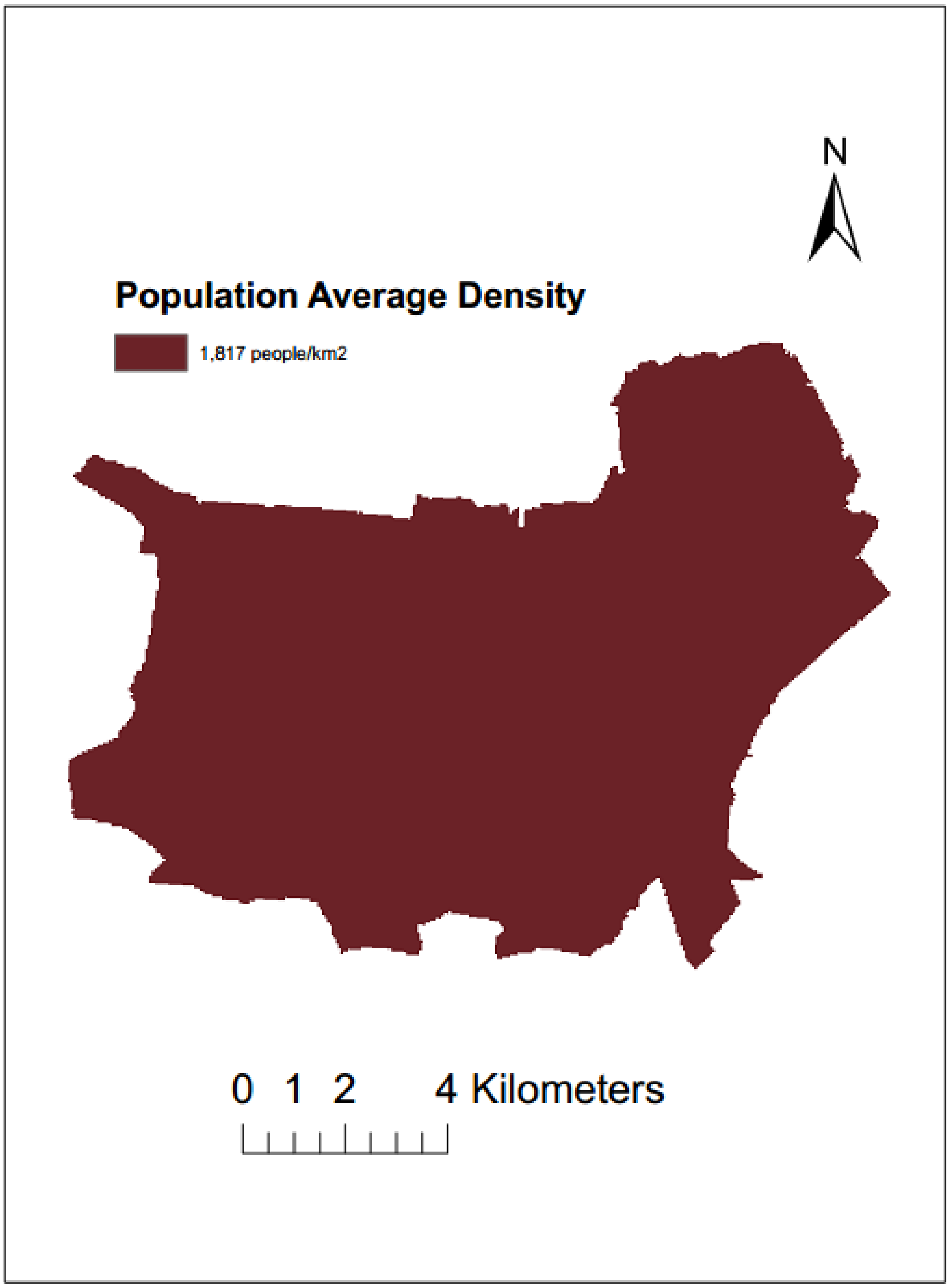

Health Care Center
Euclidean Distance
Range (m)
0 - 1,071.996075
1,071.996076 - 2,143.992149
2,143.99215 - 3,505.716893
3,505.716894 - 5,186.143172
5,186.143173 - 7,359.108188
N
0 1 2 4 Kilometers

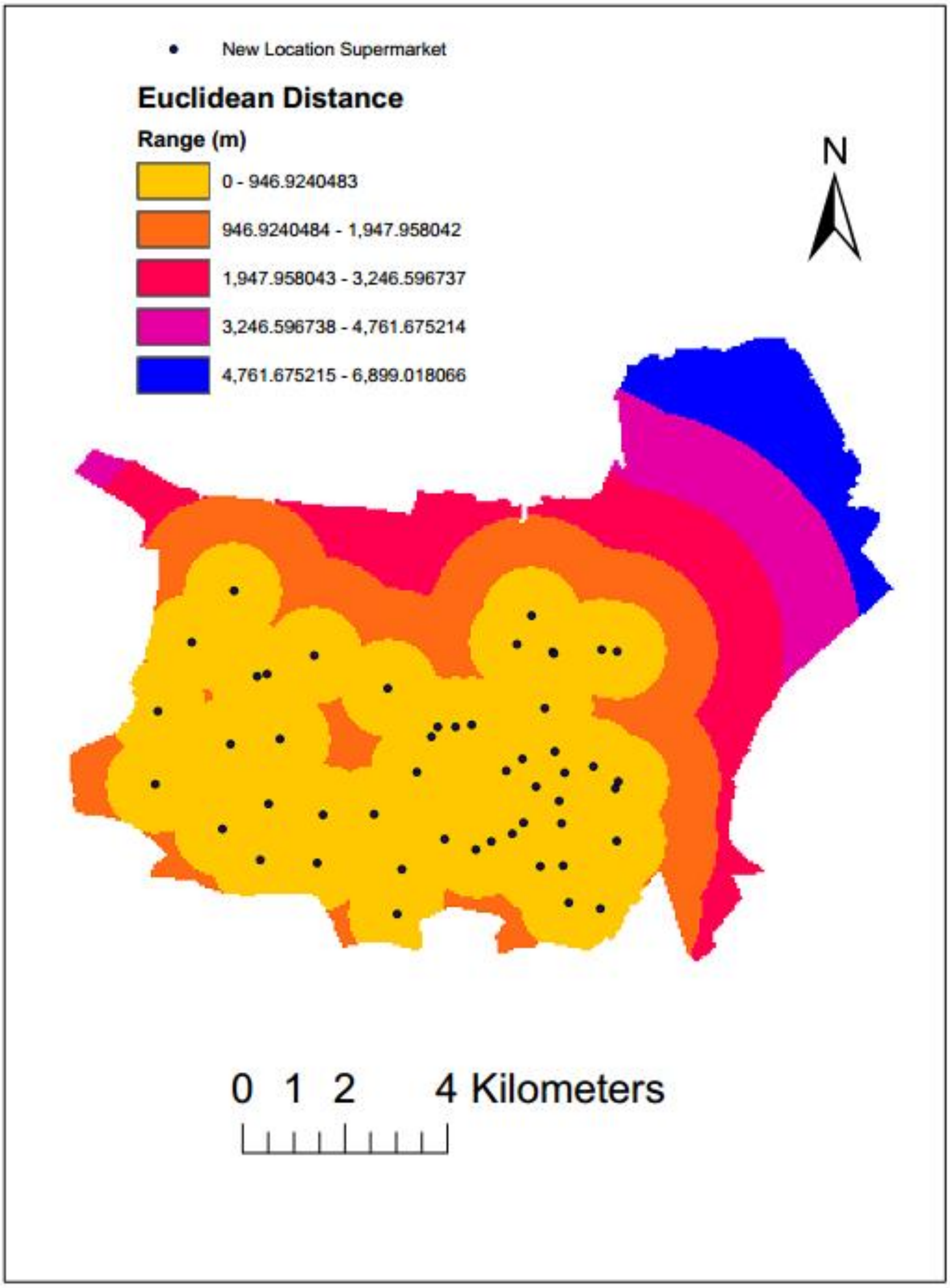

Supermarket
Euclidean Distance
Range (m)
0 - 983.915401
983.9154011 - 1,994.42311
1,994.423111 - 3,164.484668
3,164.484669 - 4,573.876999
4,573.877 - 6,781.038574
N
0 1 2 4 Kilometers

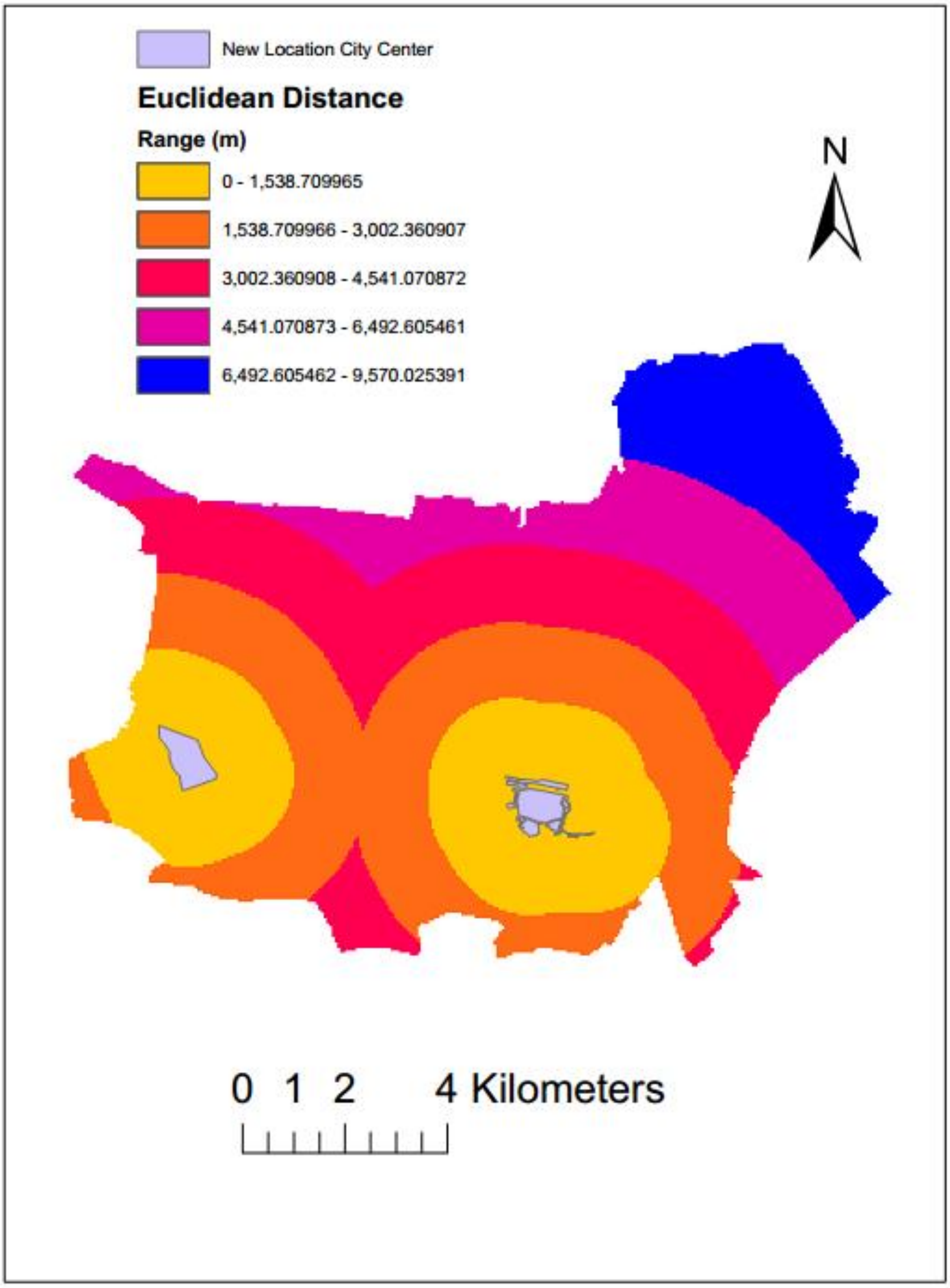

City Center
Euclidean Distance
Range (m)
0 - 1,990.570768
1,990.570769 - 3,778.02207
3,778.022071 - 5,524.849479
5,524.84948 - 7,231.052995
7,231.052996 - 10,359.09277
N
0 1 2 4 Kilometers

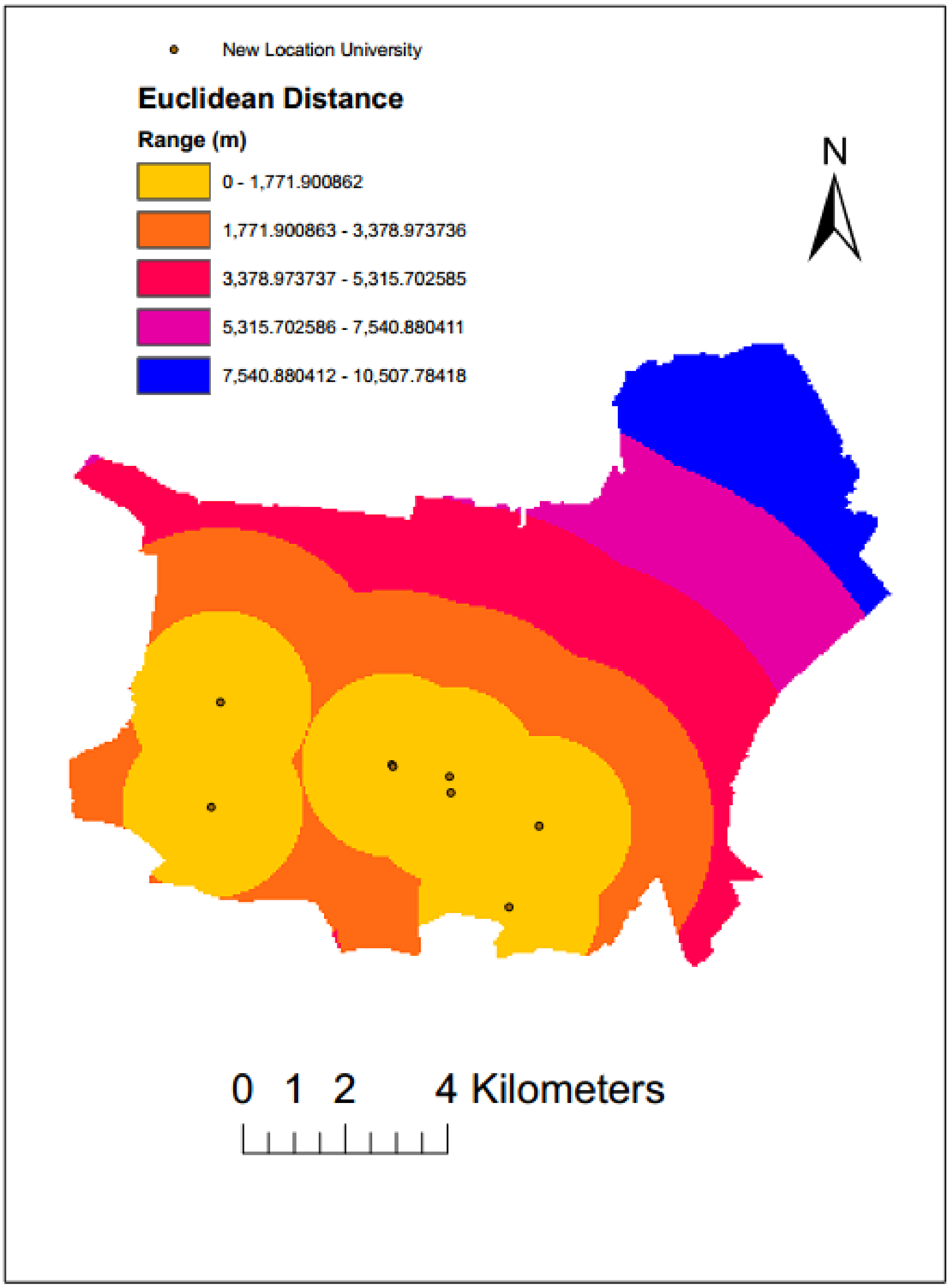

University
Euclidean Distance
Range (m)
0 - 2,019.142842
2,019.142843 - 3,749.836707
3,749.836708 - 5,480.530572
5,480.530573 - 7,499.673415
7,499.673416 - 10,507.78418
N
0 1 2 4 Kilometers


N
Population Average Age
45 years
0 1 2 4 Kilometers


N
Population Average Density
1,817 people/km2
0 1 2 4 Kilometers

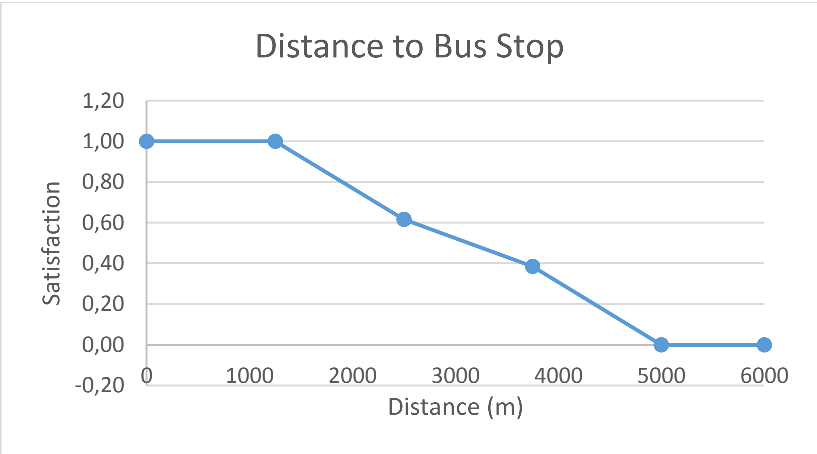

New Location Supermarket
Euclidean Distance
Range (m)
0 - 946.9240483
946.9240484 - 1,947.958042
1,947.958043 - 3,246.596737
3,246.596738 - 4,761.675214
4,761.675215 - 6,899.018066
N
0 1 2 4 Kilometers


New Location City Center
Euclidean Distance
Range (m)
0 - 1,538.709965
1,538.709966 - 3,002.360907
3,002.360908 - 4,541.070872
4,541.070873 - 6,492.605461
6,492.605462 - 9,570.025391
N
0 1 2 4 Kilometers

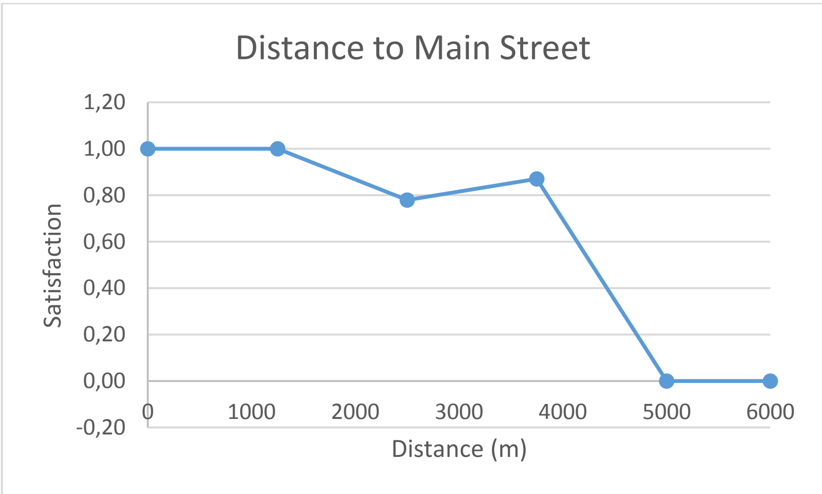

New Location University
Euclidean Distance
Range (m)
0 - 1,771.900862
1,771.900863 - 3,378.973736
3,378.973737 - 5,315.702585
5,315.702586 - 7,540.880411
7,540.880412 - 10,507.78418
N
0 1 2 4 Kilometers

A5 LSP attribute criteria

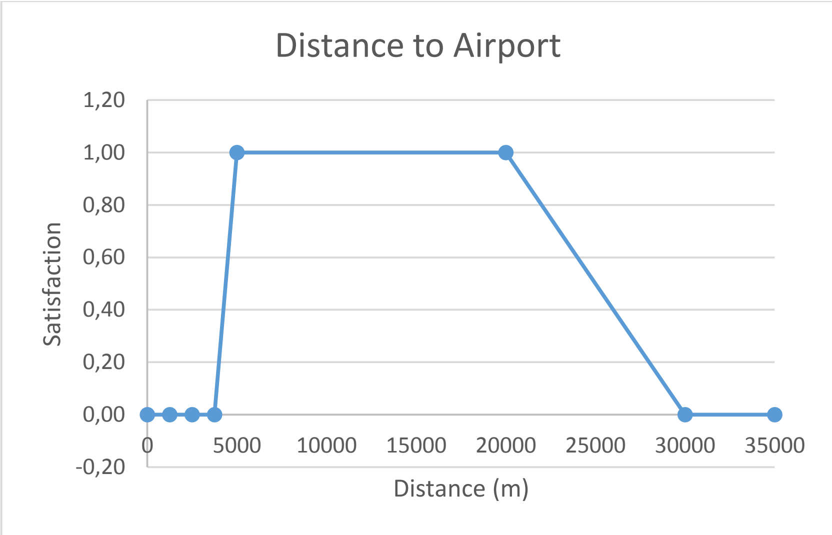
	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
BUS STOP	1250	5	3	21	55	227	4.59	1
	2500	2	4	4	14	6	3.60	0.62
	3750	0	2	2	2	0	3.00	0.39
	5000	0	1	0	0	0	2.00	0



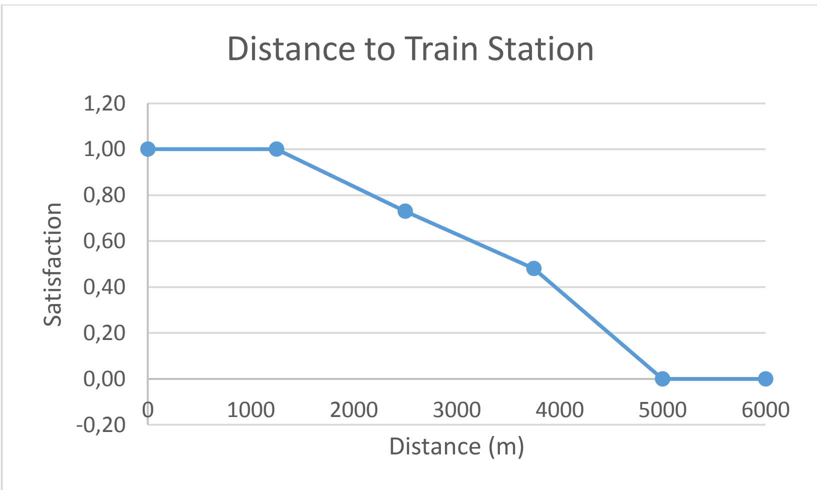
	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
MAIN STREET	1250	6	3	34	67	176	4.41	1
	2500	0	0	9	16	9	4.00	0.78
	3750	0	0	3	4	5	4.17	0.87
	5000	1	1	1	1	0	2.50	0



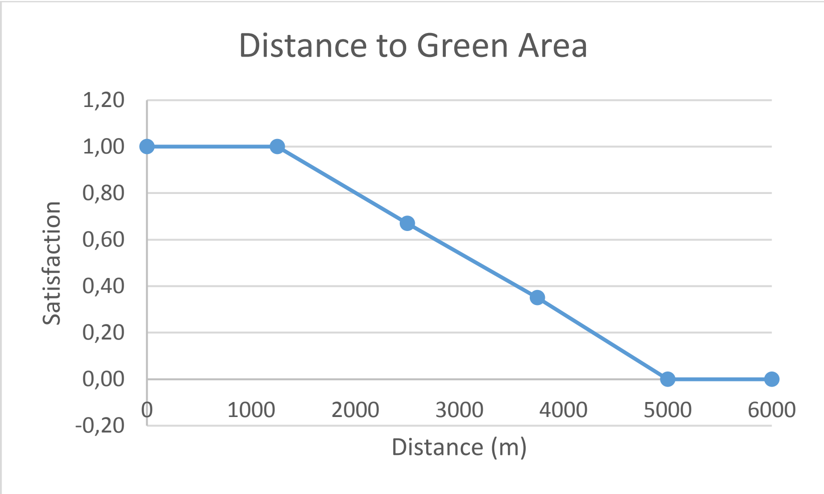
AIRPORT	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
	1250	0	0	0	0	0	#DIV/0!	0
	2500	0	0	0	0	0	#DIV/0!	0
	3750	0	0	9	2	6	3.82	0.00
	5000	11	9	106	70	53	3.58	1.00



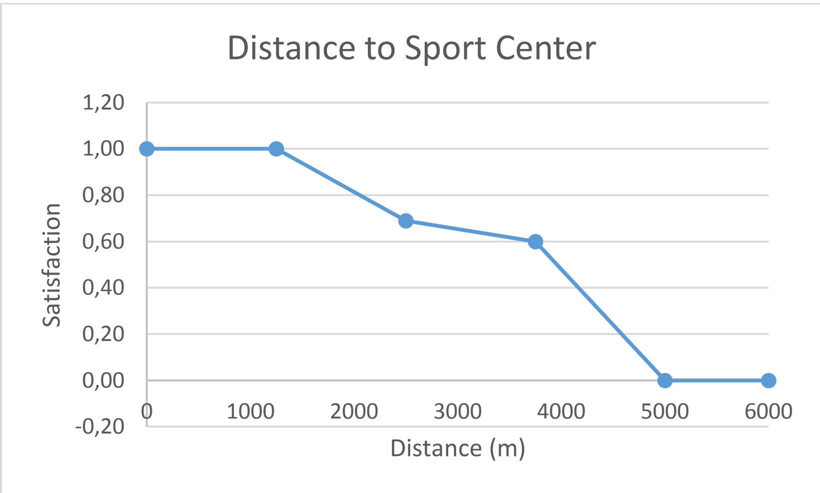
TRAIN STATION	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
	1250	1	1	1	13	84	4.78	1
	2500	3	2	9	70	50	4.21	0.73
	3750	0	7	29	32	17	3.69	0.48
	5000	5	12	16	7	1	2.68	0



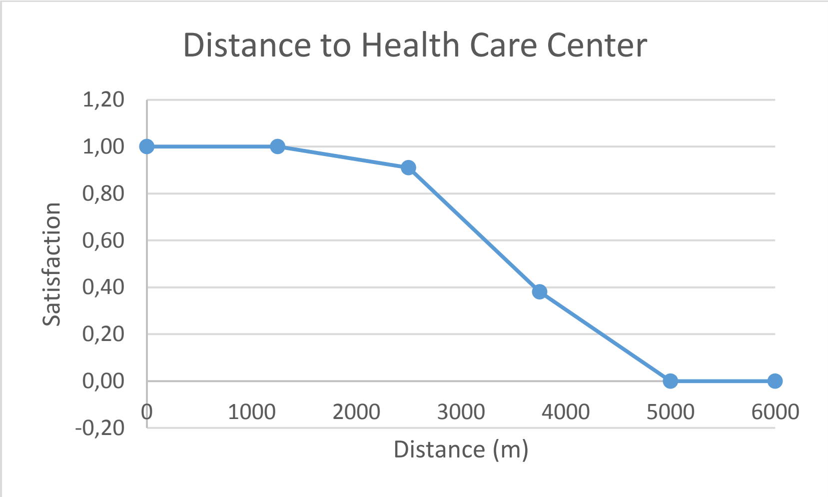
GREEN AREA	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
	1250	2	1	22	85	87	4.29	1
	2500	4	6	18	44	25	3.82	0.67
	3750	1	4	12	12	3	3.38	0.35
	5000	1	2	3	3	0	2.89	0



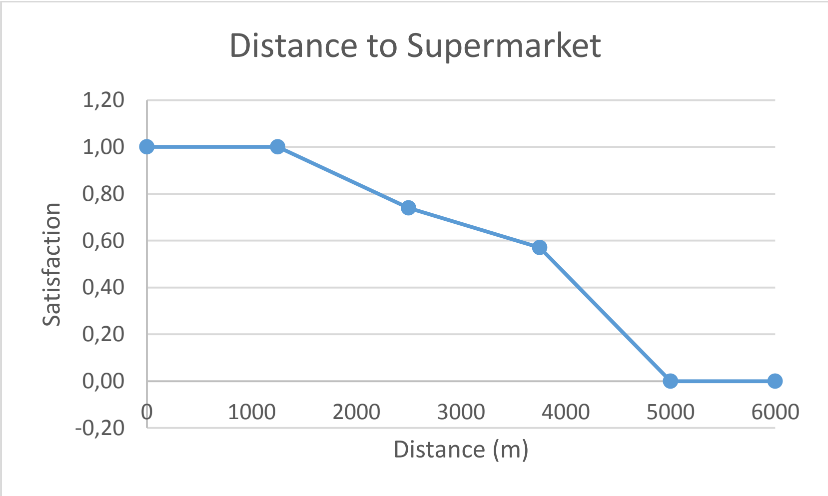
SPORT CENTRE	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
	1250	0	0	16	33	63	4.42	1
	2500	4	2	31	52	30	3.86	0.69
	3750	0	9	18	36	13	3.70	0.60
	5000	2	12	5	1	3	2.61	0



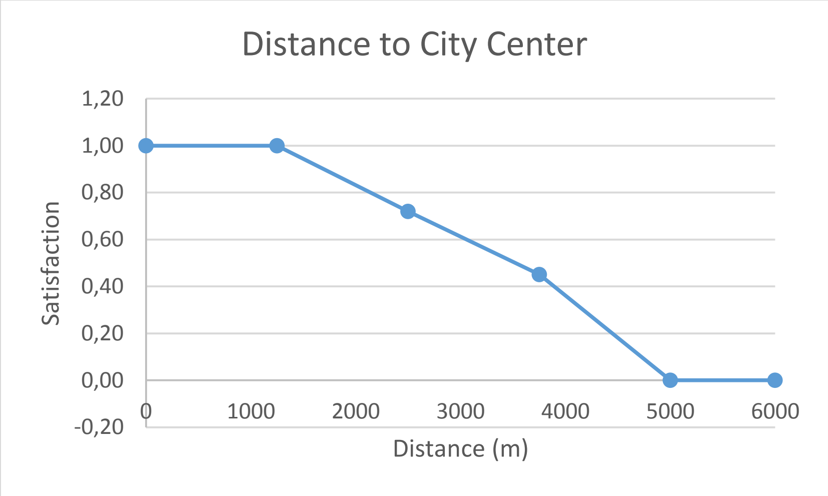
	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
HEALTH CARE	1250	1	0	10	23	22	4.16	1
	2500	1	1	21	45	33	4.07	0.91
	3750	2	2	36	23	13	3.57	0.38
	5000	3	6	21	11	5	3.20	0



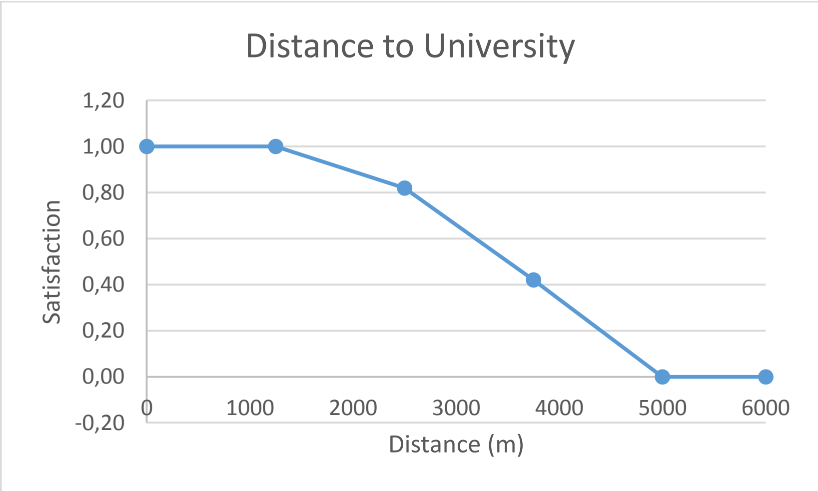
	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
SUPERMARKET	1250	5	0	10	65	216	4.65	1
	2500	0	4	12	24	18	3.97	0.74
	3750	0	1	0	3	0	3.50	0.57
	5000	1	1	1	0	0	2.00	0



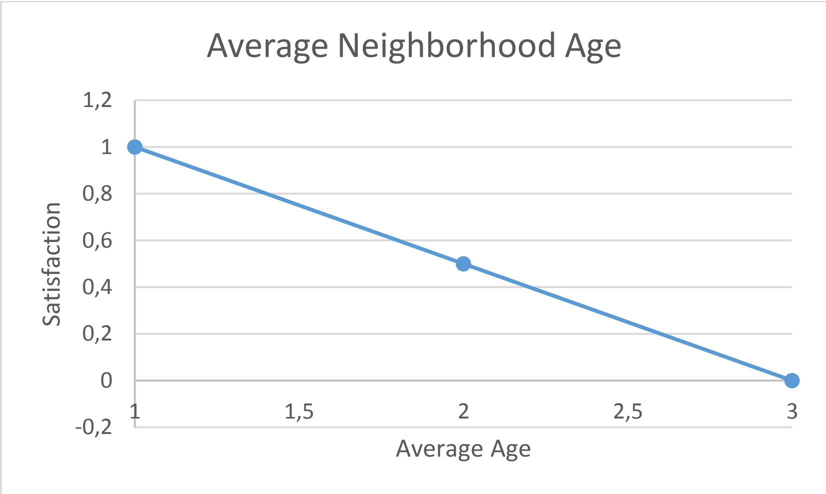
	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
CITY CENTER	1250	1	0	6	14	75	4.69	1
	2500	1	4	13	62	57	4.24	0.72
	3750	1	7	16	41	16	3.79	0.45
	5000	1	15	9	18	1	3.07	0



	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
UNIVERSITY	1250	1	1	1	4	48	4.76	1
	2500	1	2	5	40	59	4.44	0.82
	3750	1	11	26	57	16	3.68	0.42
	5000	10	21	24	22	6	2.92	0

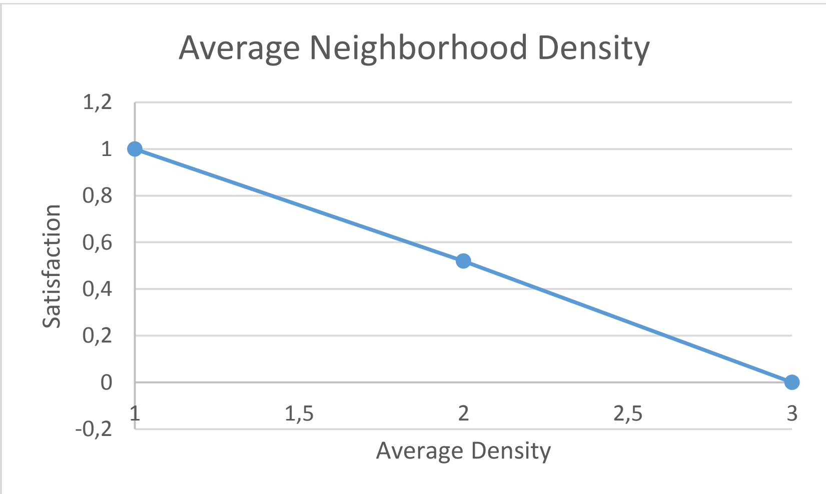


AVG AGE	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
	Young	3	3	33	61	31	3.87	1
	Middle	1	10	99	65	5	3.35	0.50
	Senior	1	2	7	2	0	2.83	0



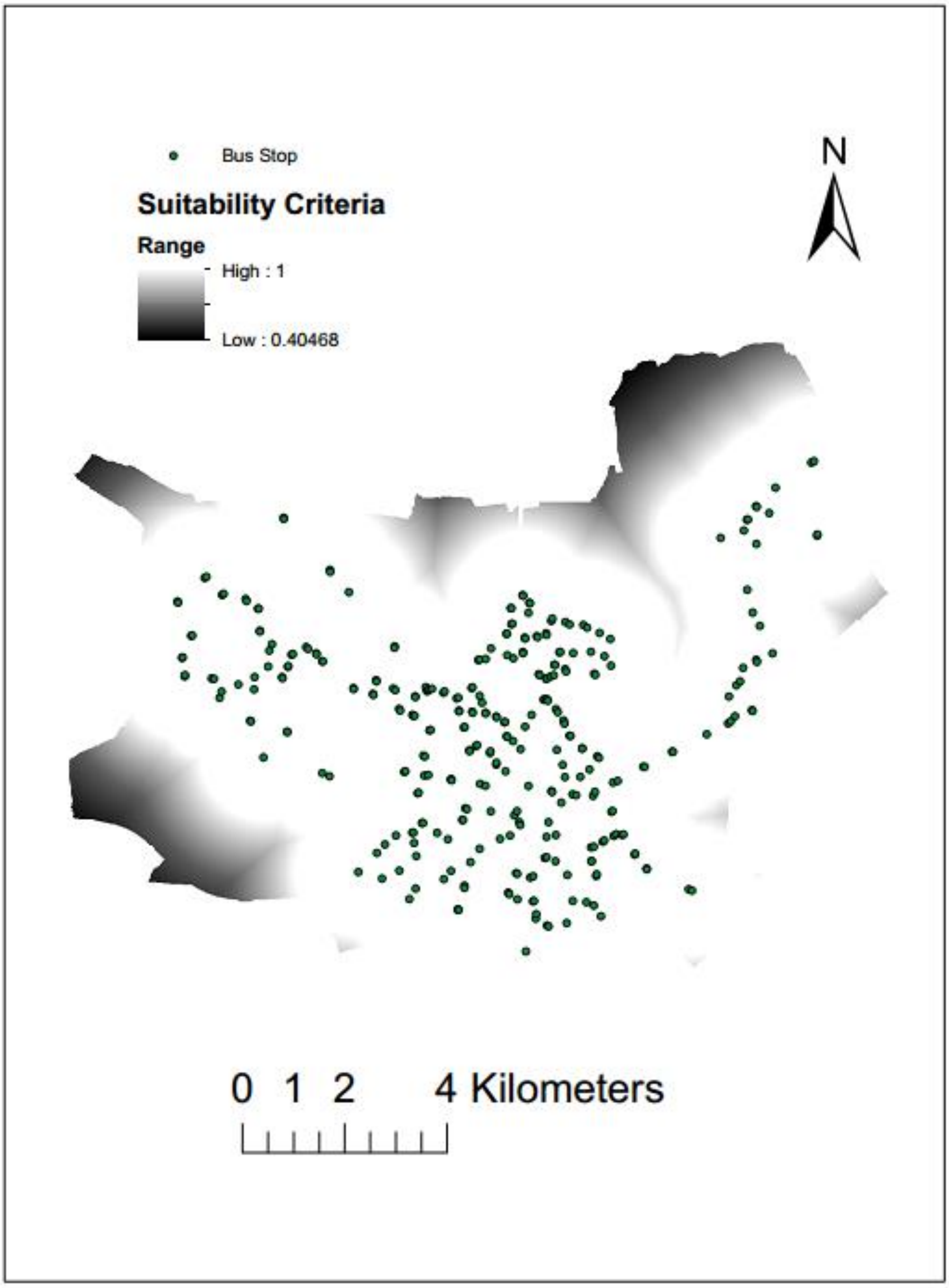
Where 1 represents young age, 2 middle age and 3 senior age.

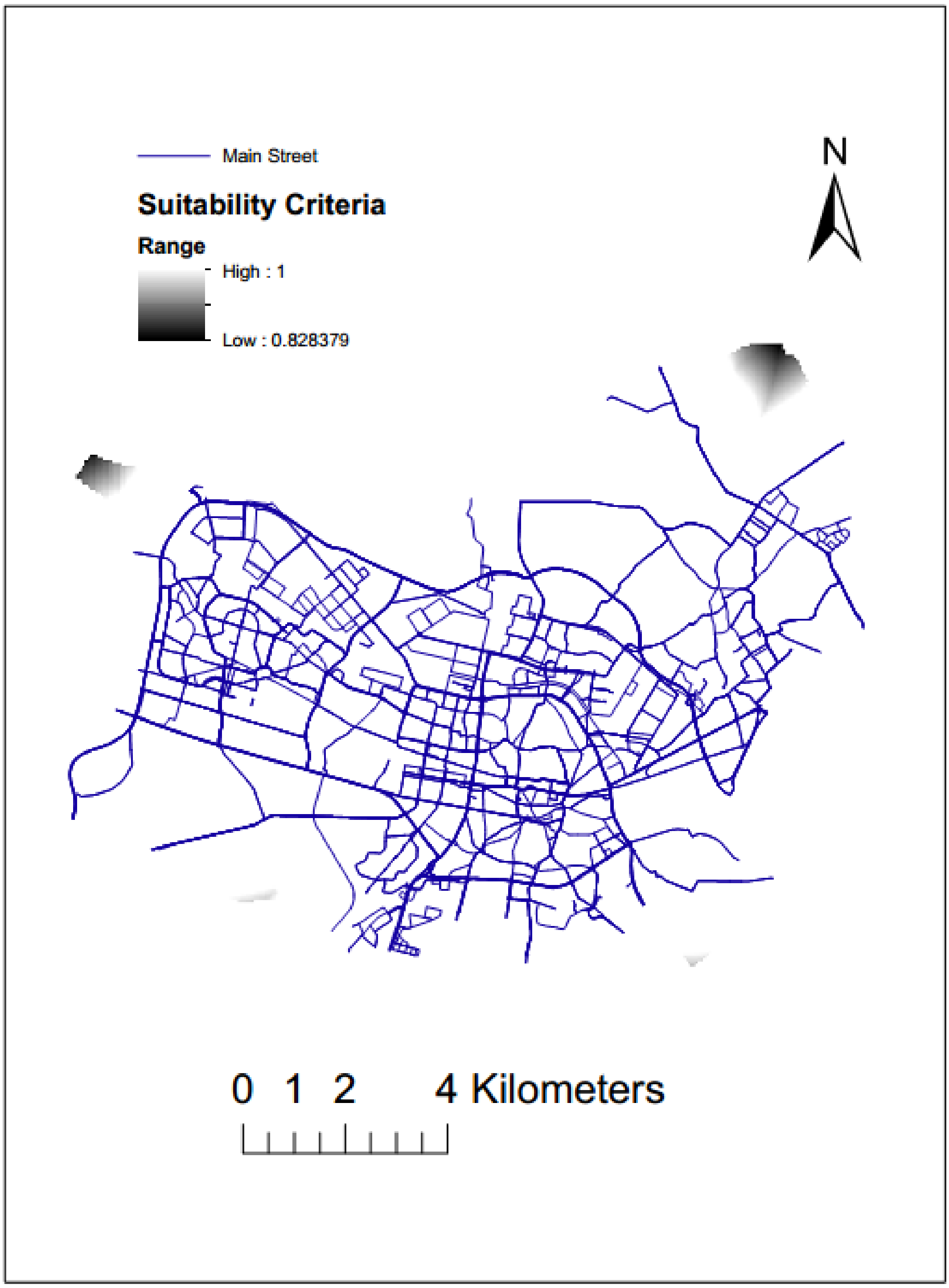
AVG DENSITY	DISTANCE (m)	VERY DISSATISFIED	DISSATISFIED	NEUTRAL	SATISFIED	VERY SATISFIED	W. AVG	STANDARD
	Low	0	0	5	9	4	3.94	1.00
	Mid	1	7	87	101	24	3.64	0.52
	High	1	4	42	24	2	3.30	0

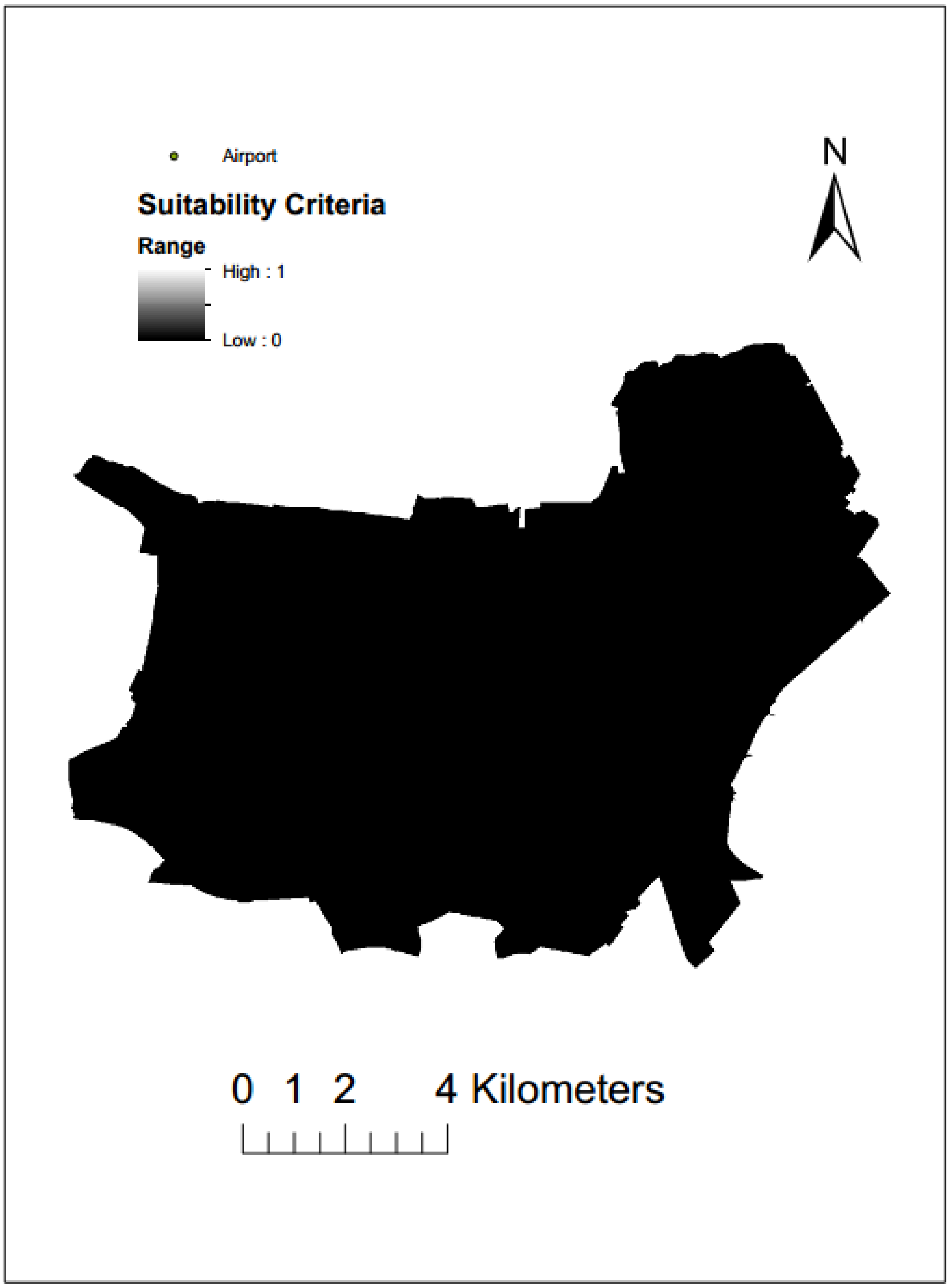


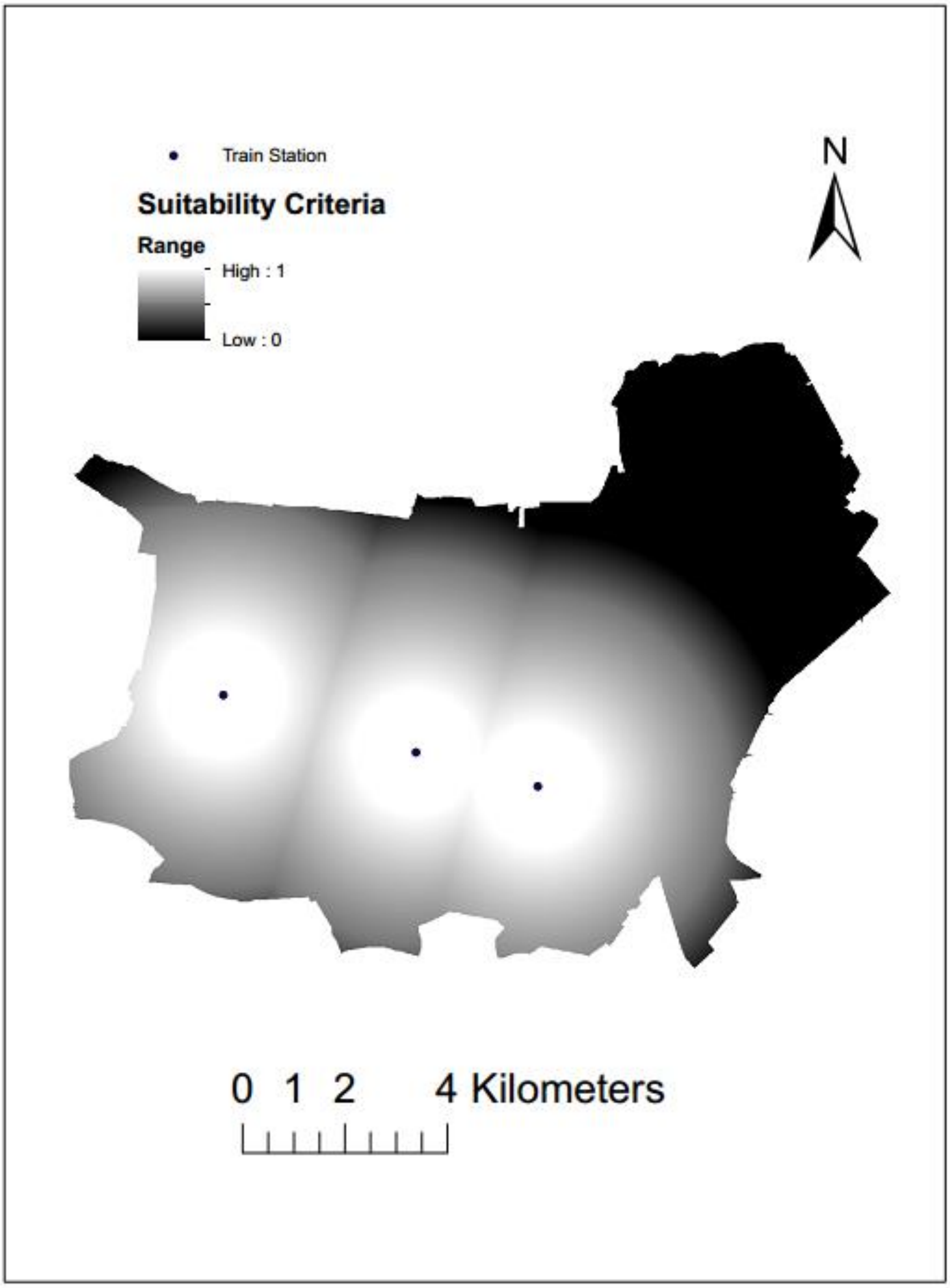
Where 1 represents low density, 2 mid density and 3 high density.

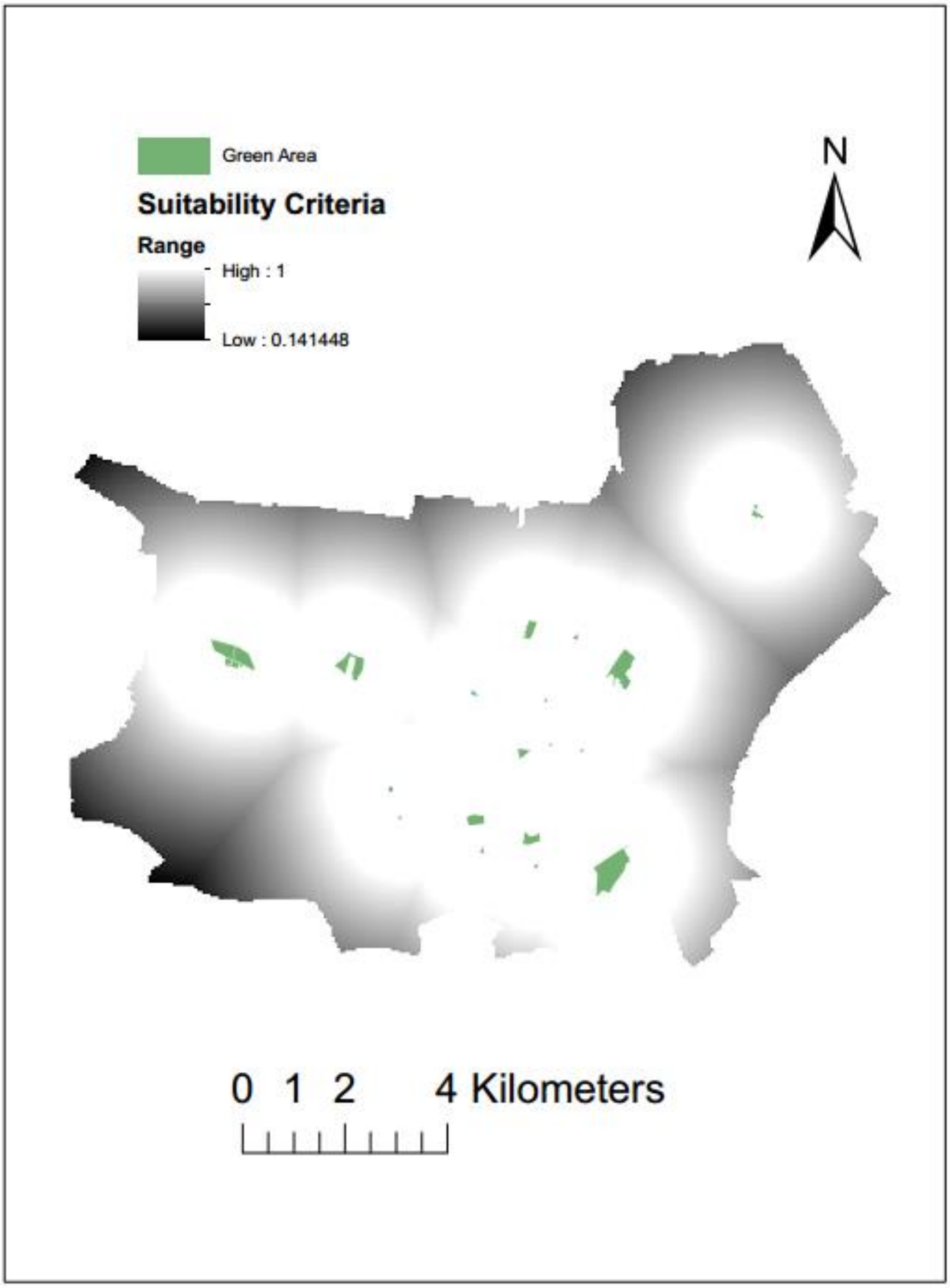
A6 LSP input files

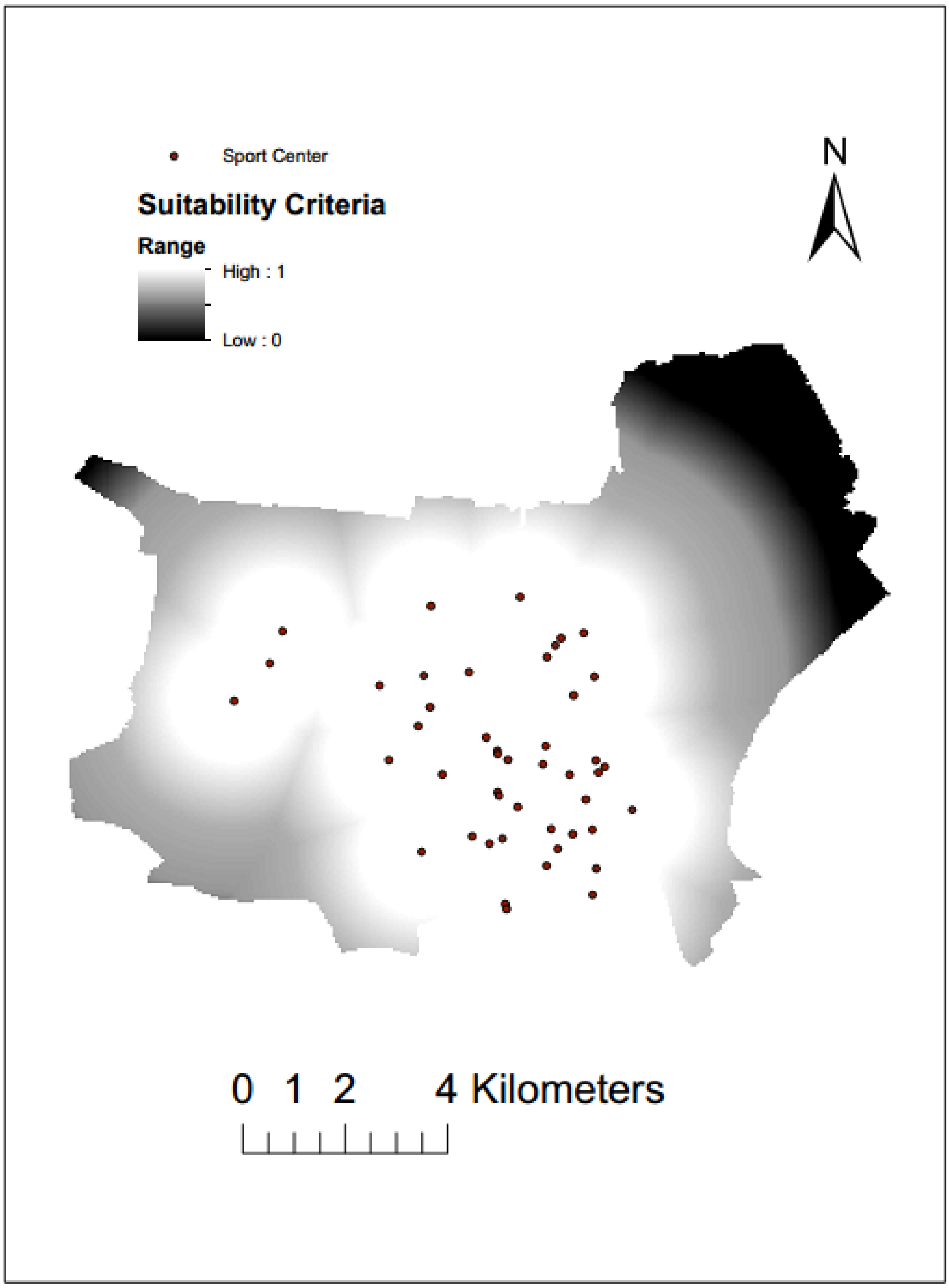


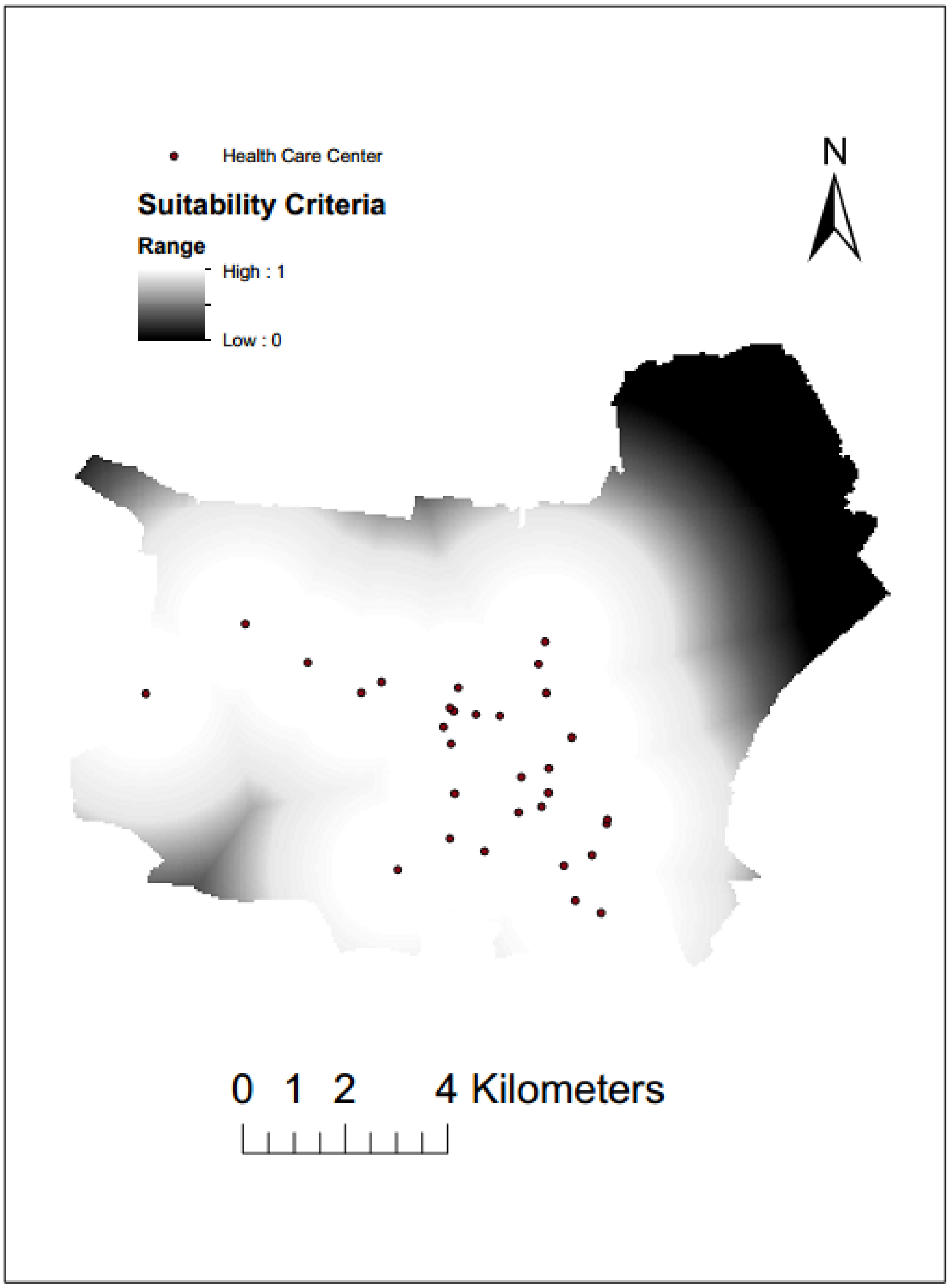

Main Street
Suitability Criteria
Range
High : 1
Low : 0.828379
N
0 1 2 4 Kilometers

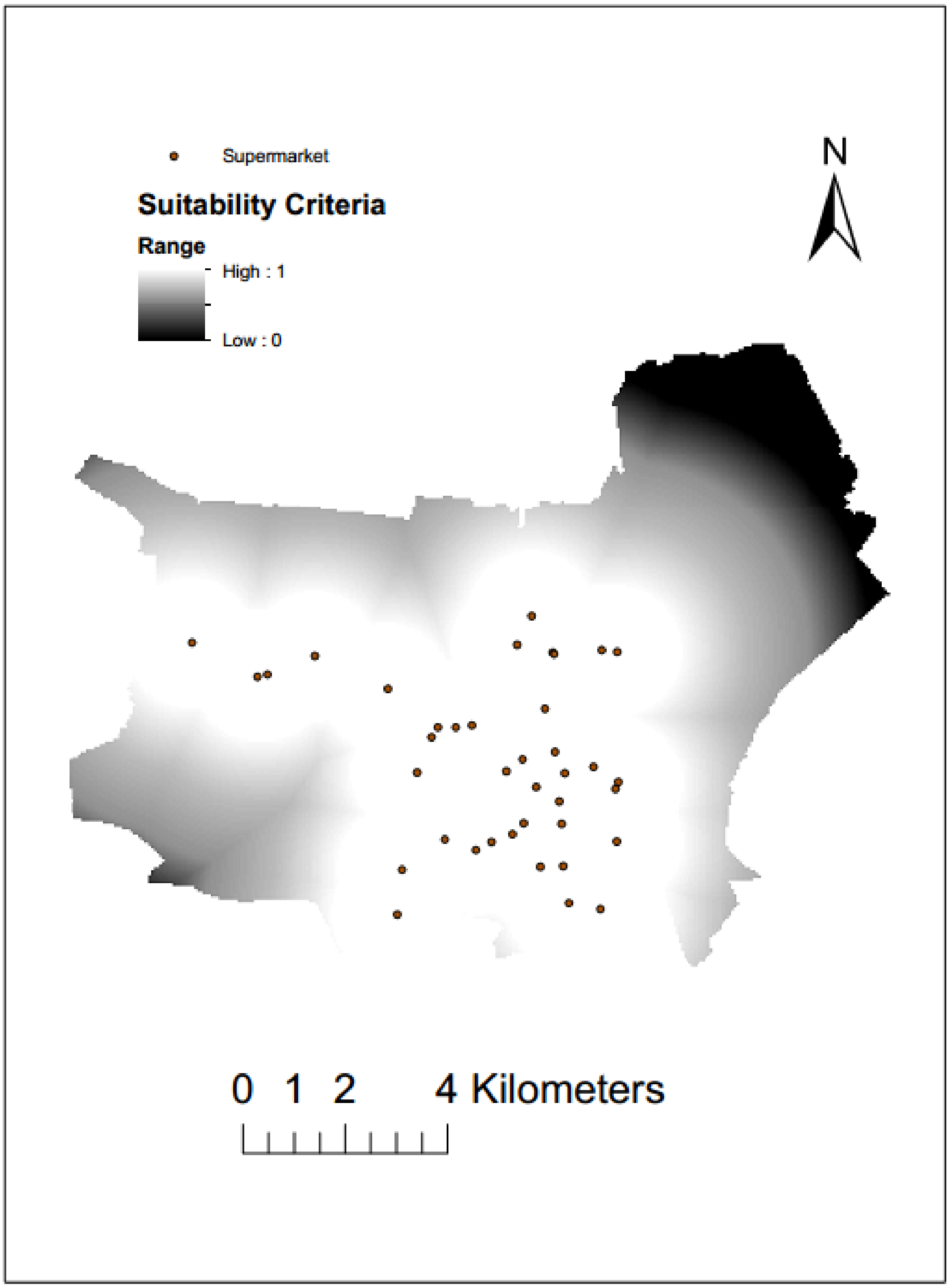

Airport
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

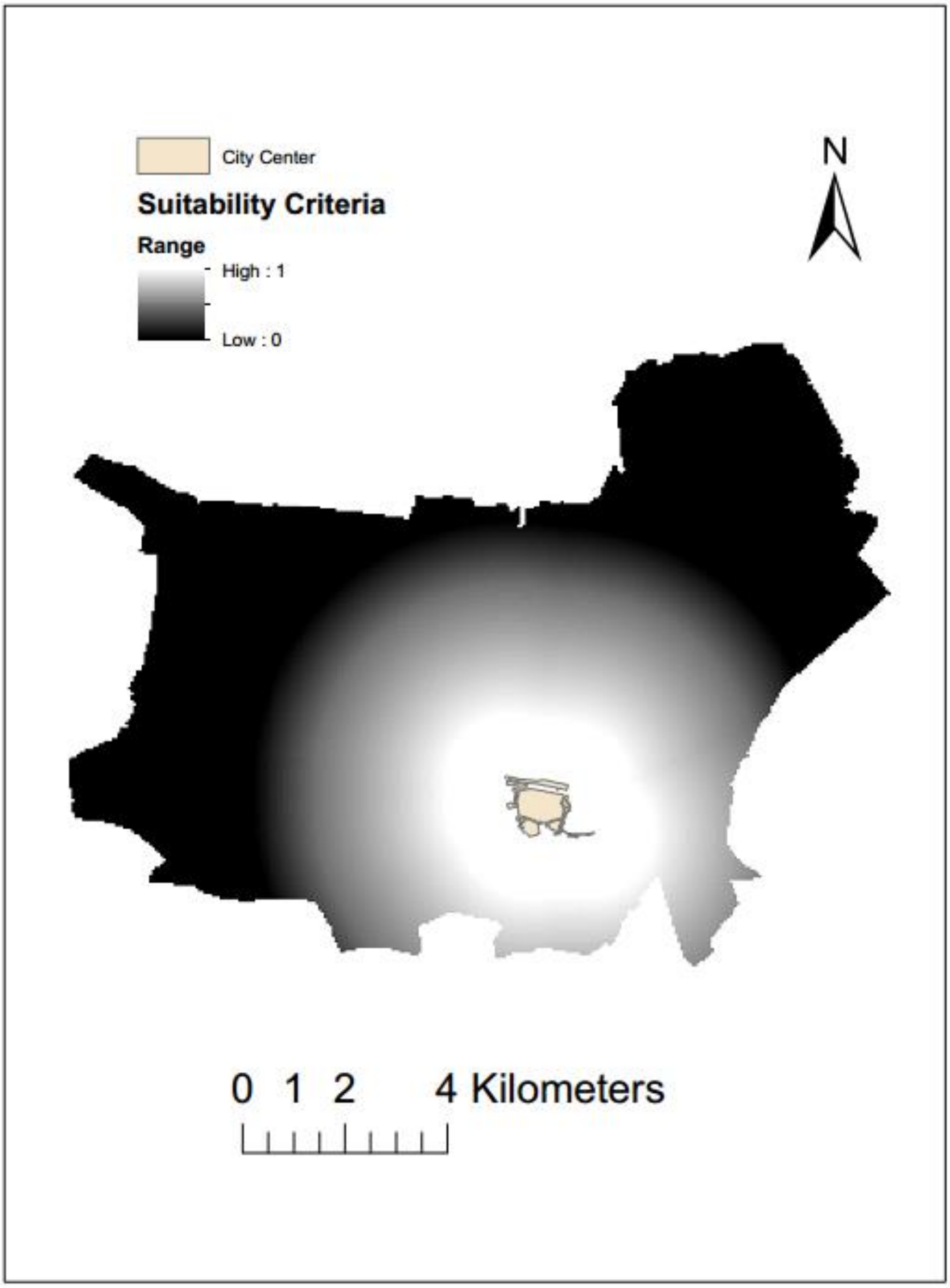

Train Station
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

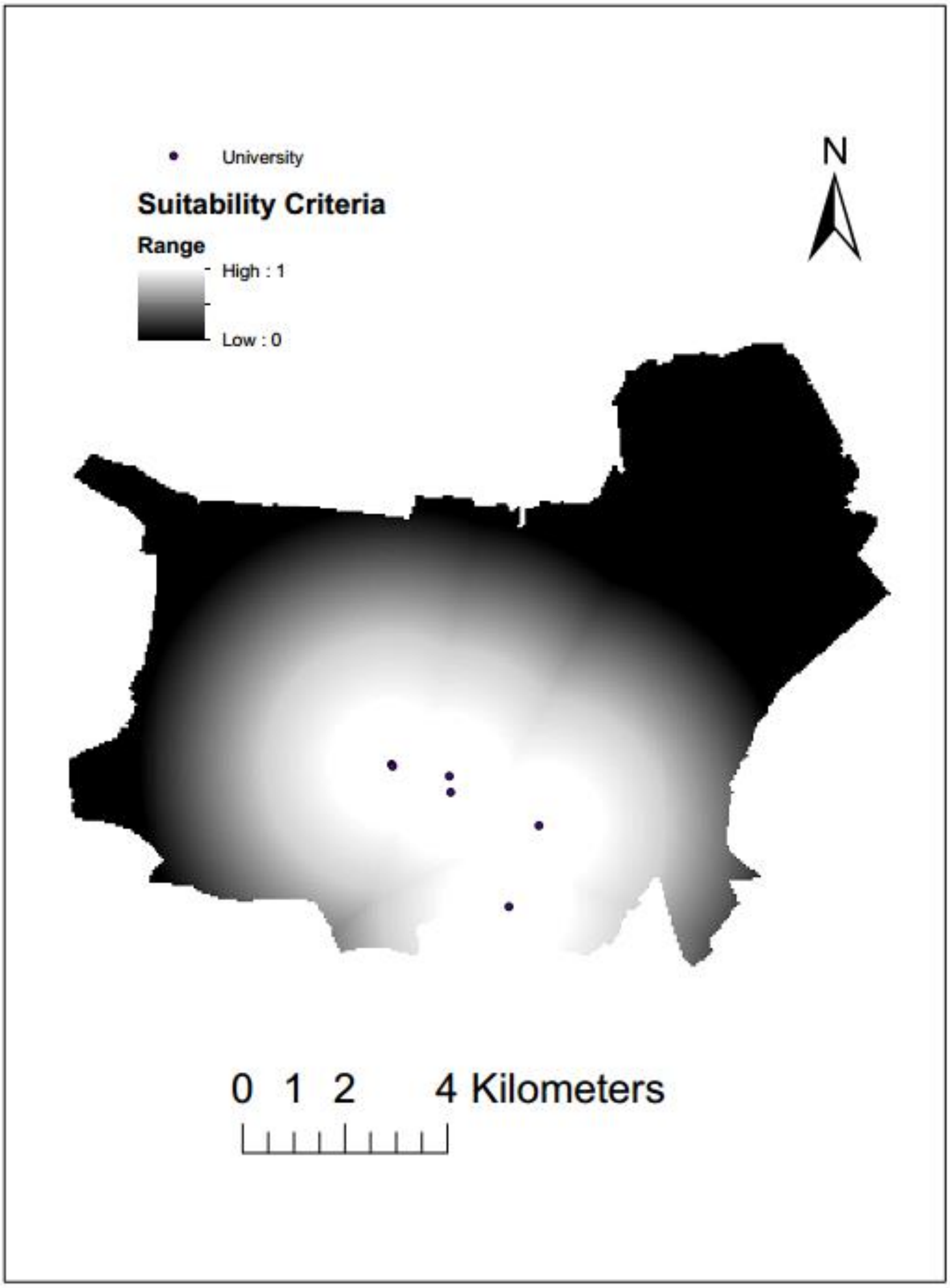

Green Area
Suitability Criteria
Range
High : 1
Low : 0.141448
N
0 1 2 4 Kilometers

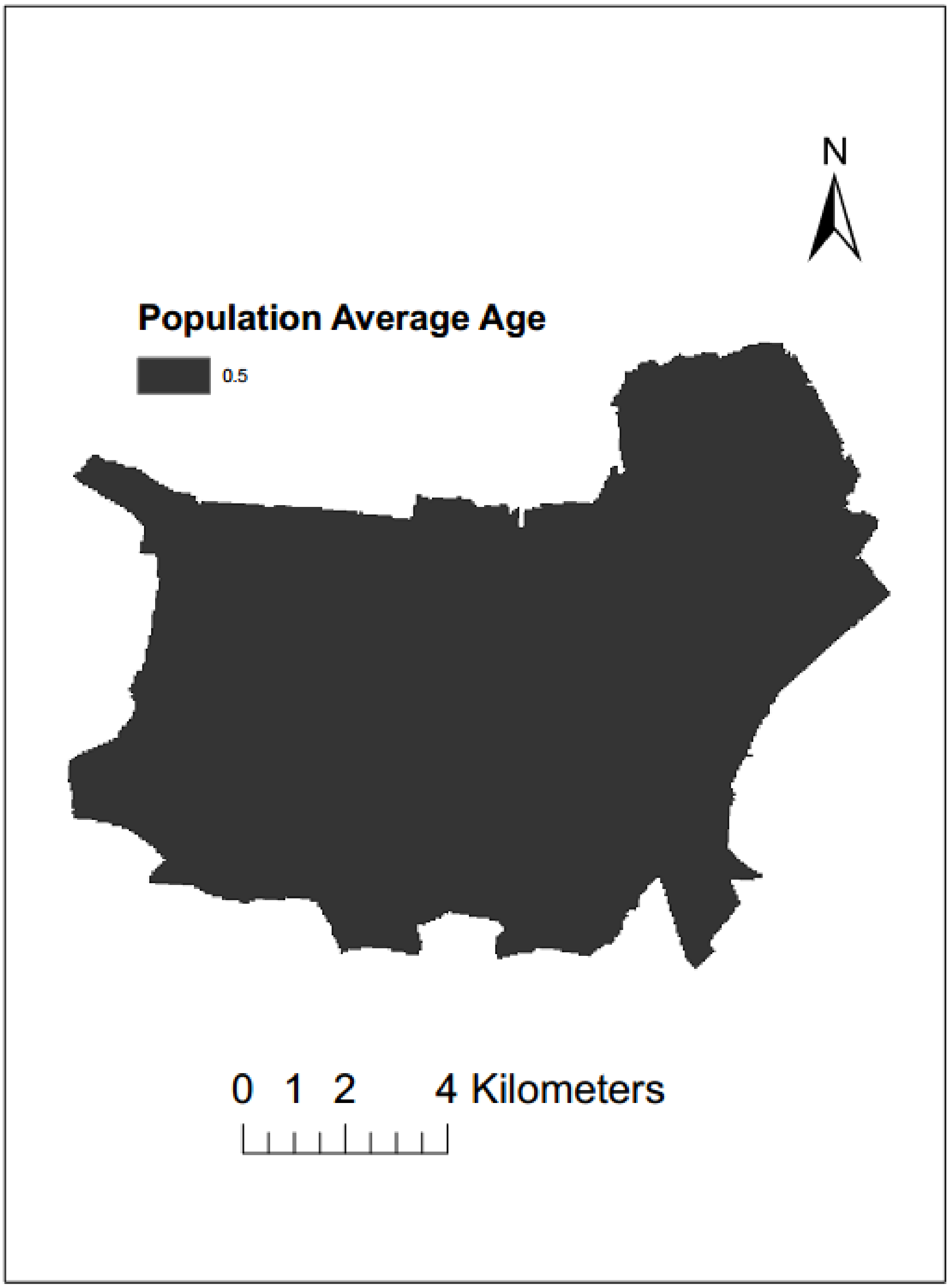

Sport Center
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

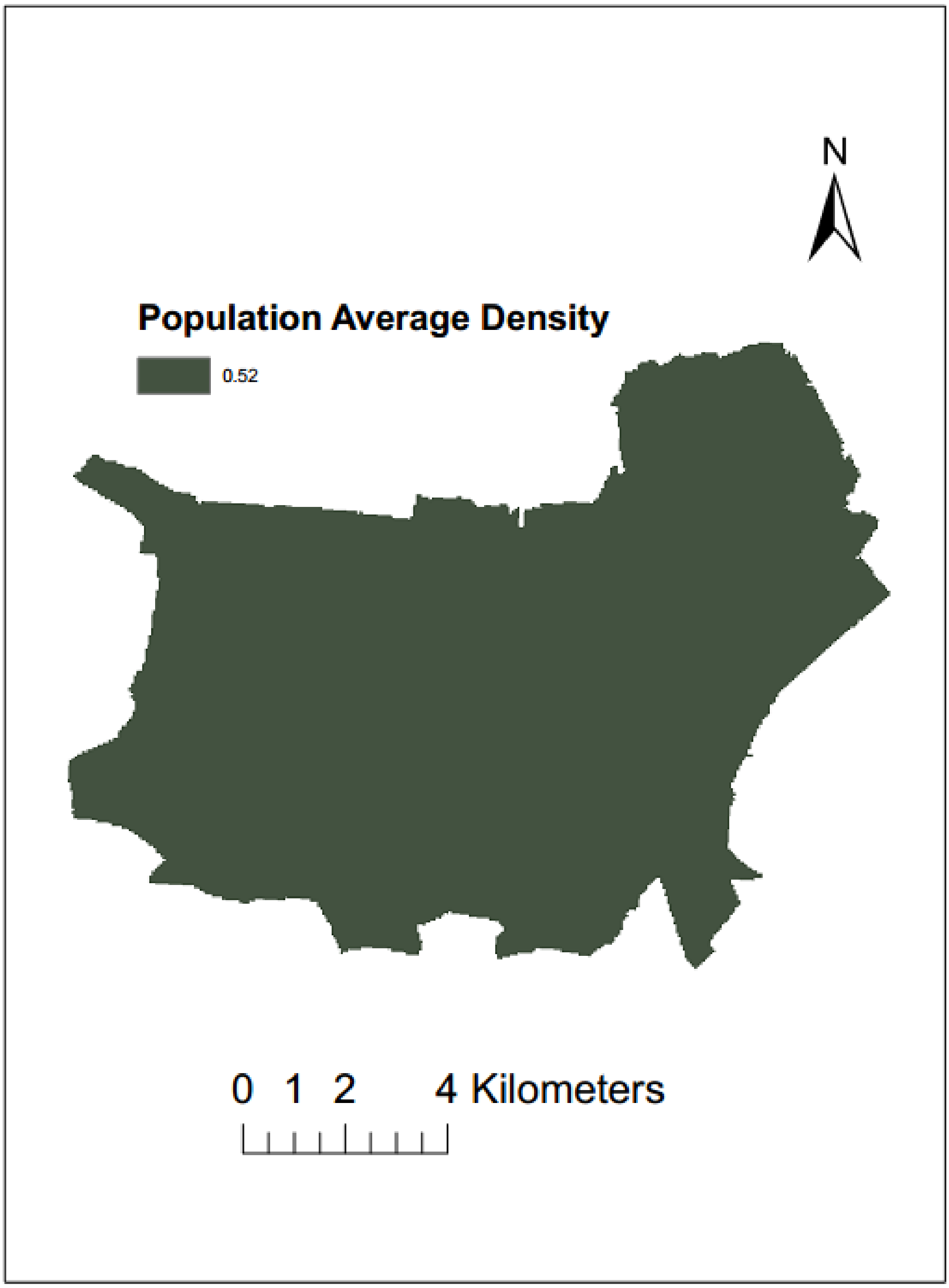

Health Care Center
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

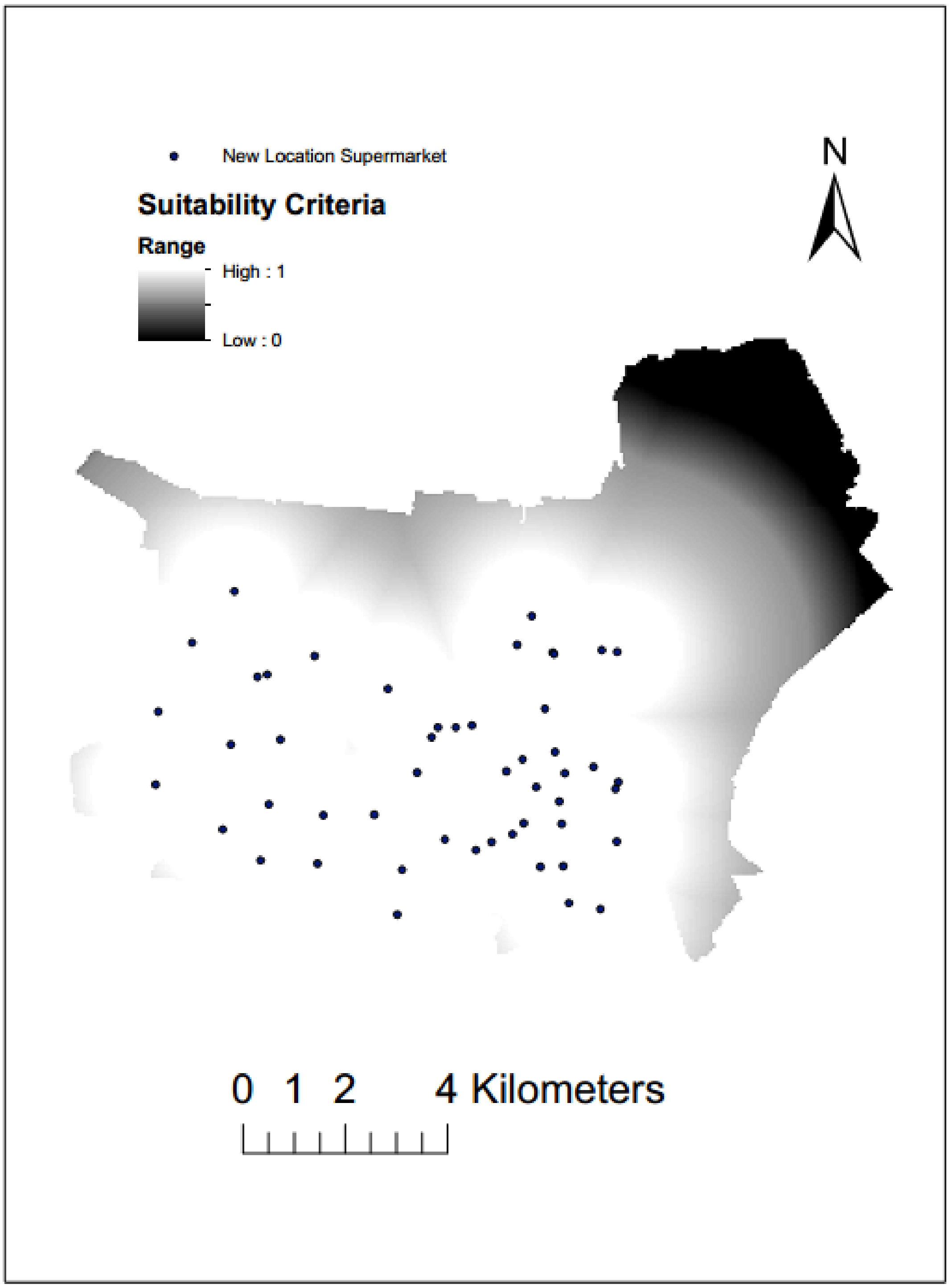

Supermarket
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

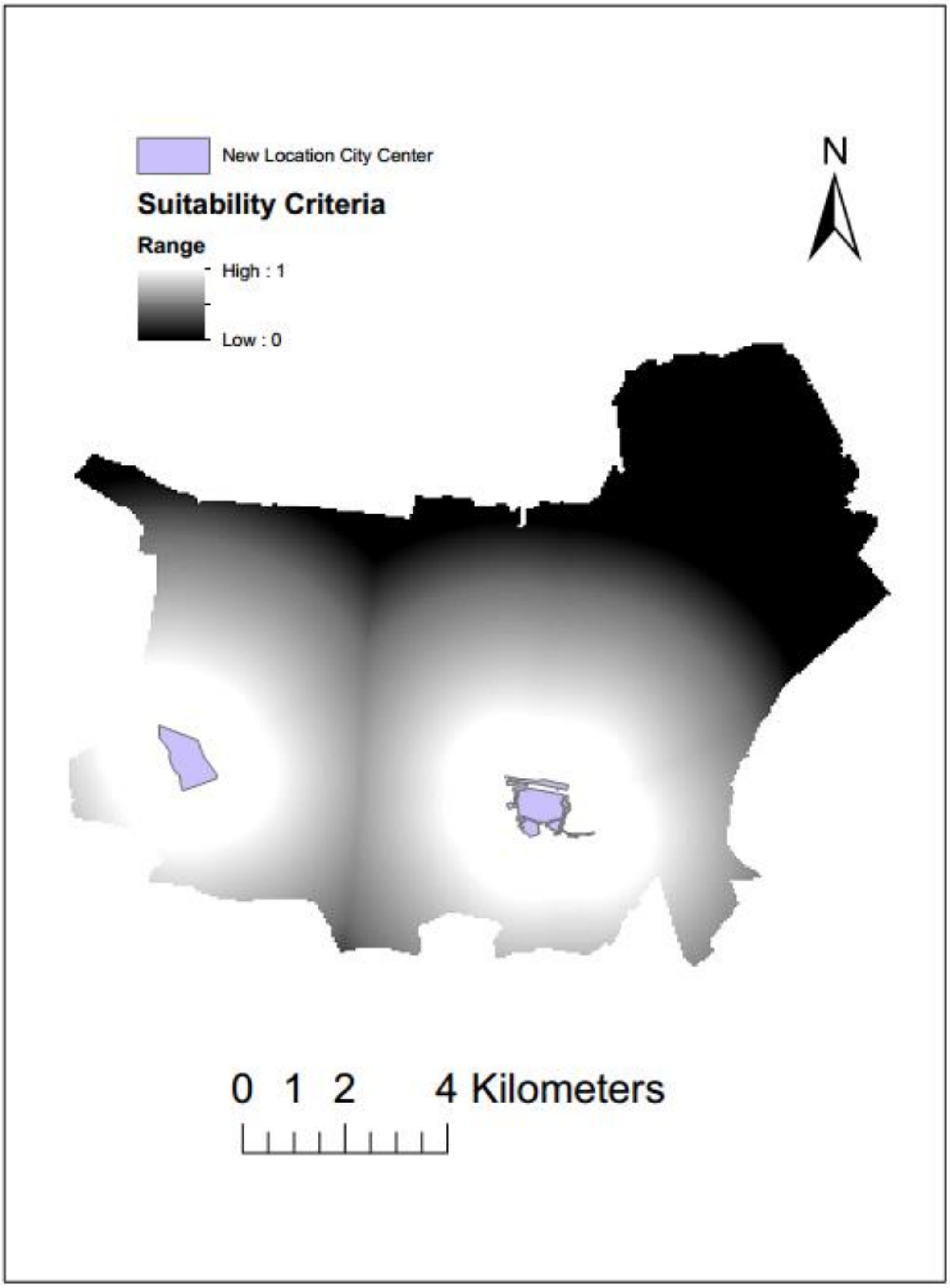

City Center
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

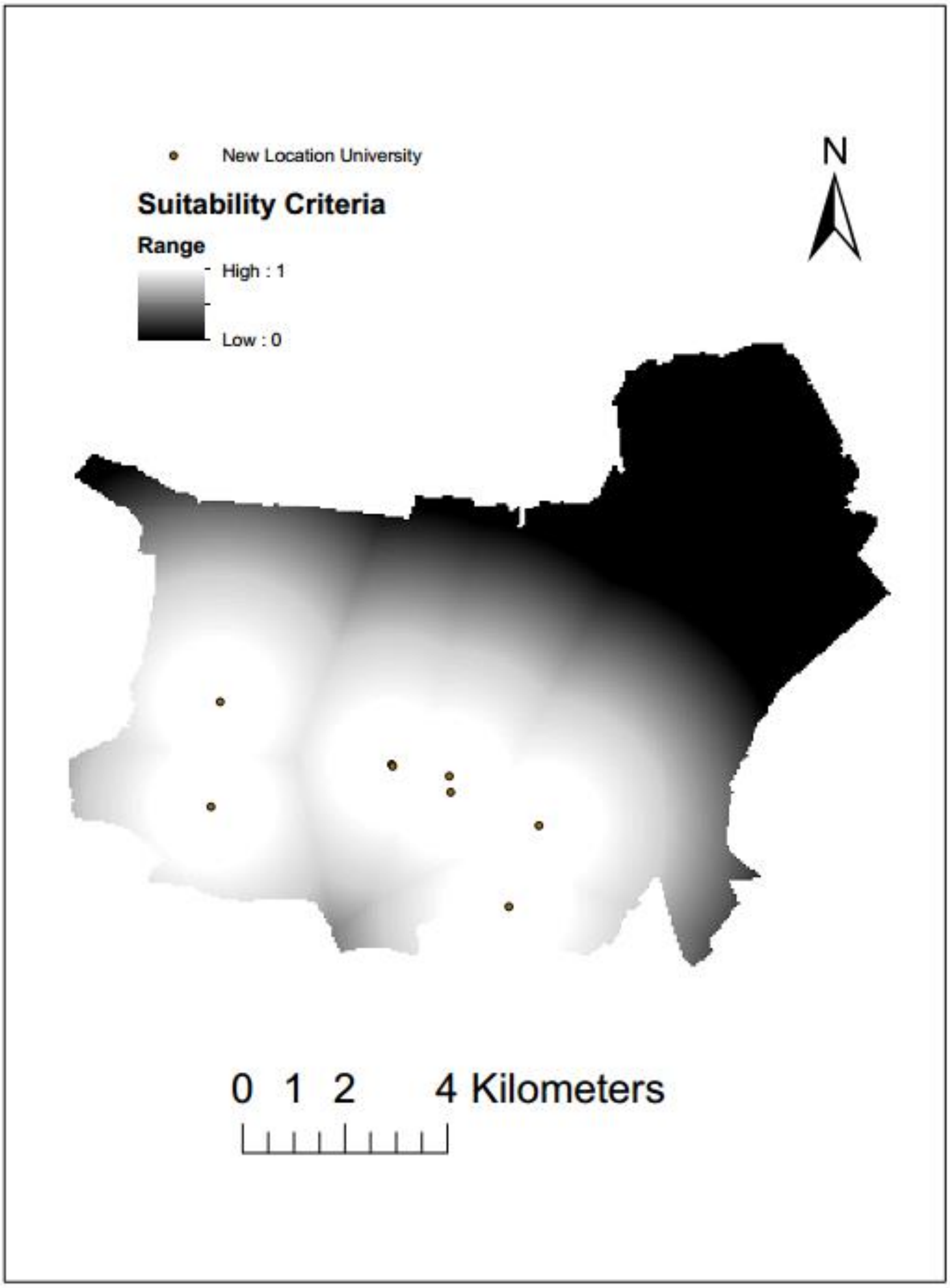

University
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers


N
Population Average Age
0.5
0 1 2 4 Kilometers


N
Population Average Density
0.52
0 1 2 4 Kilometers


New Location Supermarket
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

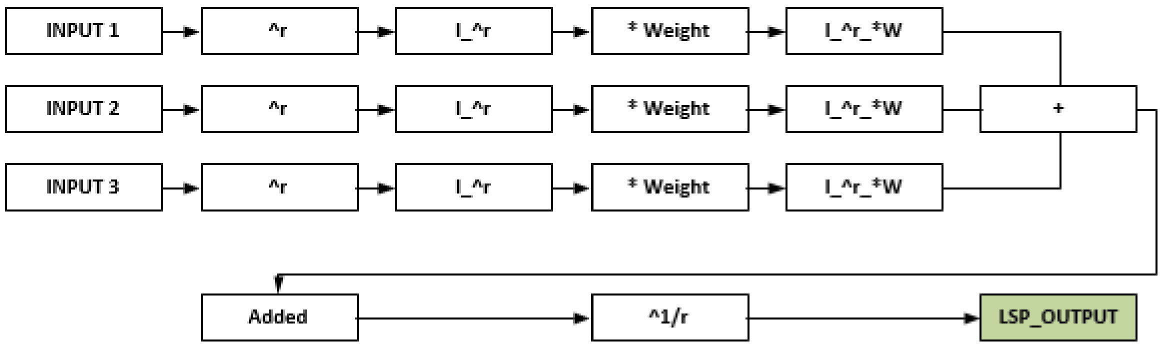

New Location City Center
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers


New Location University
Suitability Criteria
Range
High : 1
Low : 0
N
0 1 2 4 Kilometers

A7 WPM and CPA modeled functions

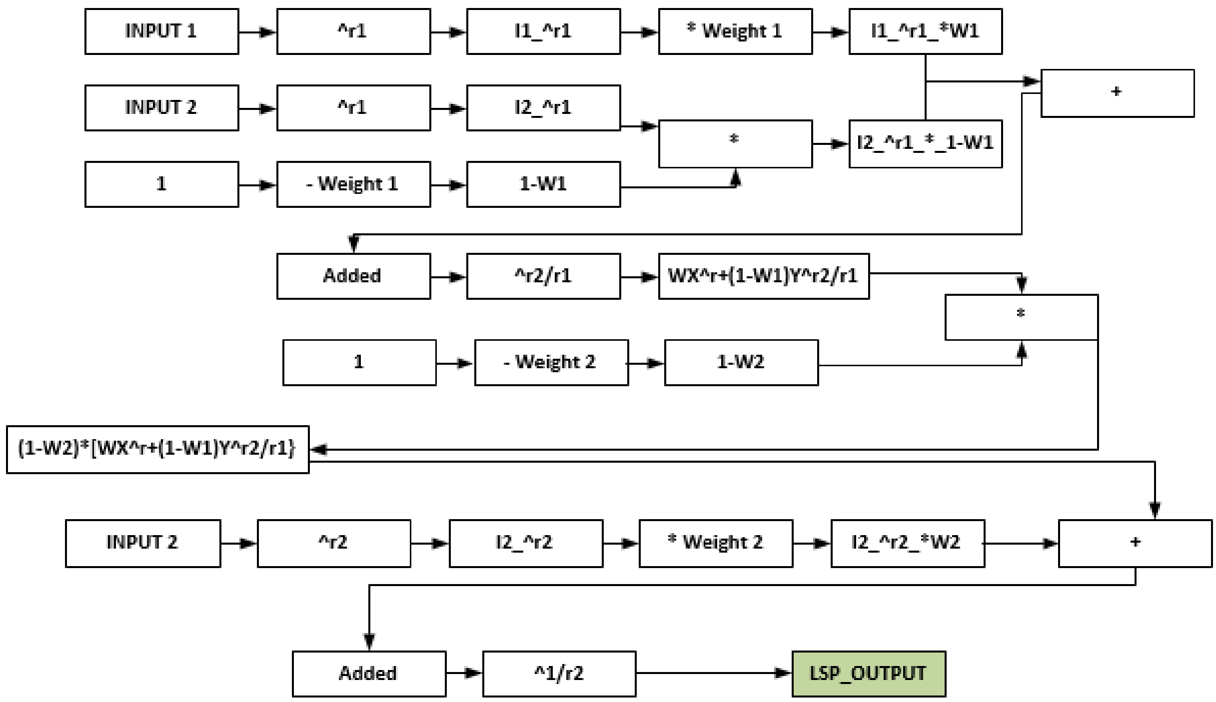
The WPM function is modeled into ARCGIS using the following structure:

$$GCD(X_1, \dots, X_n) = [W_1 X_1^r + \dots + W_n X_n^r]^{1/r}$$

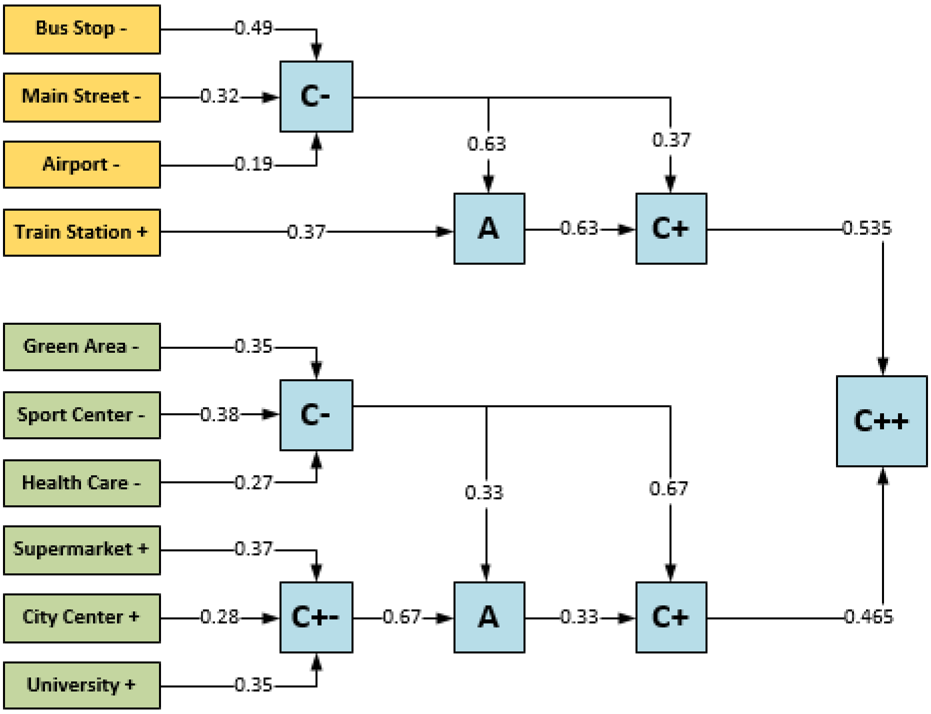


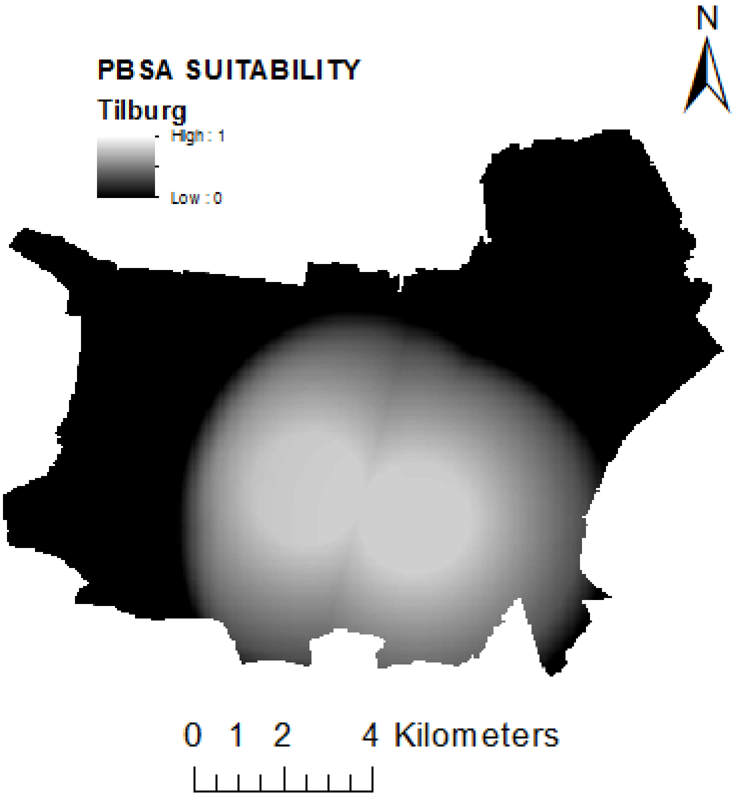
The CPA function is modeled into ARCGIS using the following structure:

$$S(X,Y) = [(1 - W_2)[W_1 X^{r_1} + (1 - W_1) Y^{r_1}]^{r_2/r_1} + W_2 X^{r_2}]^{1/r_2}$$



A8 LSP with strengthened operators suitability map





A9 LSP with relaxed operators suitability map