SUSTAINABLE TRANSPORT SOLUTIONS FOR THE CONCEPT OF SMART CITY: THE CASE OF UMEÅ

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ABSTRACT

Few studies suggest the use of alternative transport modes in an attempt to manage urban landscapes in more sustainable ways. Generally, sustainable development is associated with mixed land-use and density decisions. The present study aims to investigate all those factors which contribute to reduction of automobile dependency. Furthermore, it is an effort to perceive how mixed land use measures may be linked to travel patterns within urban landscape. Finally, it will be investigated from a theoretical point of view whether big data can affect transport and improve the quality of the city.

Keywords

Urbanization, Automobile Dependency, Smart Growth, Travel Behavior, Sustainability, Mixed-land use, Big Data Analytics
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1. INTRODUCTION

1.1 BACKGROUND

The world today is confronted with rapid growth of the urban population. According the United Nations (UN), in 1950, 30 per cent of the world’s population was urban. Recent estimates suggest that today more than half of the world’s population live in urban areas, while until 2050, according to UN projections this percentage is estimated to peak the level of 66 per cent (United Nations, Department of Economic and Social Affairs, Population Division, 2014, p.1).

Based on the approach published by the Population Division of the UN Department of Economic and Social Affairs, it is most likely the present rates of population growth to become greater in the future. The current world population is expected to reach 8.9 billion inhabitants on 2030, 9.7 billion on 2050, while until 2100 it seems to reach the level of 11.2 inhabitants (United Nations, 2015). For this reason, the last few years there has been a growing interest in dealing with urban growth, due to an increasing concern over the rapid pace of urbanization. Hence, it is reasonable how governments around the world try to develop policies in order to manage efficiently this deliberate rapid urbanization.

The increasing number of people living in cities bring new challenges on how to address the rapid expansion of urban areas but with a more efficient and both functional way. The uneven expansion of urban space known as urban sprawl (Oueslati, Alvanides & Garrod, 2015, p.1595) seems to be more automobile dependent, while on the other side as it has been observed high population densities are more possible to reduce automobile dependency within an urban area (Cervero, 2013, p.3).

In fact this growing trend of the population creates the need for more infrastructure and, undeniably, as the traffic congestion becomes more intense, pollutant emissions threaten the health condition of residents, while at the same time urban living becomes unbearable (Lakshminarasimhan, 2016, p.2). Fast growing cities in combination with the evolution of technology make conventional data management methods weak against the complexity of modern cities (Lakshminarasimhan, 2016, p.3).

Previous studies indicate that urban spatial structures can have an impact on travel behavior (Naess, 2012, p.21). Similarly, urban spatial attributes (land-use mix and density) appear as crucial determinant of decision making on vehicle ownership (Frank & Pivo, 1994, p.44). Previous research has documented that the expansion of low density suburbs around the city center, defined as urban sprawl, cause an increase on automobile dependency, which usually corresponds to traffic congestion, emissions and sound pollution (Wang & Hofe, 2007, p.321-322).
This paper investigates how land use factors concerning population density and mixed land use influence travel behavior. A vital element when it comes to the support of sustainability is the knowledge of the reasons that shape automobile dependency as well as the reasons that can prevent or force the use of alternative modes of transportation.

1.2 Working Smart with Sustainability

Modern cities require a more intelligent management of Information and Communication Technologies (ICT) in order to deal with problems such as gas emissions and congestion and to provide more sustainable options for transport activities. Urban functionality can be improved with appropriate distribution of uses which is a key factor in the management of traffic flows. Now it can be managed more efficiently through the constant observation of daily human activities patterns through smart devices. Big Data management enters dynamically and shapes the general urban landscape by proposing more efficient solutions.

Smart City (SC) concept in an effort to tackle rapid urbanization focuses on technology to develop sustainable smart solutions. City’s attempt to gain intelligence is based exclusively on the use of ICT (YIN ChuanTao, et al.; Osman, Elragal & Bergvall-Kåreborn, 2017). These technologies are comprised of large volumes of data commonly known as Big Data that require analysis to draw conclusions and make decisions (Osman, Elragal & Bergvall-Kåreborn, 2017).

Intelligent technology is now widespread in every corner of the globe and offers opportunities for development with an enormous impact on all areas of life from sporting activities to home care. Smart mobile apps calculate sports activities based on the physical movement of users. Also, sensors in cars understand driver behavior. Android based applications receive data from accelerometers, GPS and capture sounds and through the data analysis driving patterns can be recognized. Driver behavior can be monitored and thus vehicles acquire intelligence for finding optimal routes, offering greater perimeter security after obstacle identification and saving energy (Kalra & Bansal, 2014, p.699-702).

The smart city gathers large volumes of data on urban trends, environmental issues and the socio-economic indicators (Bibri & Krogstie, 2017, p.3). As Kitchin refers «big data are characterised by high volume, velocity, variety, exhaustivity, resolution and indexicality, relationality and flexibility» (Kitchin, 2013, p.262). Marr (2016) argues that it should be given more emphasis on the diversity of big data and on their analysis than simply focusing on the volume. Undoubtedly, data collection is vital, but it is even more important to know how to analyze and manage big data in order to extract the right results. There seem to be many companies who have difficulties in managing large volumes of information (Marr, 2016, p.294). The next stage of development of these data concerns the use of real-time data for decision-making which can also be promise greater accuracy in the field of urban planning (Marr, 2016, p.295).
Los Angeles is one of the cities with heavy traffic congestion while big data seem to be part of the current traffic management. Big data technologies are capable to transform ways people travel. In the streets of Los Angeles, magnetic sensors were placed in each intersection, so that traffic flows smoothly anticipating any traffic disruption. Also, in case of an accident, it regulates traffic flows based on real time updates in an effort to decongest roads (Lakshminarasimhan, 2016, p.3). It is remarkable how intelligent systems have the ability to collect information and respond to traffic flows without human intervention. In 2009, San Francisco introduced a smartphone app-based taxi services which connects users with drivers. Uber was the company that used this app based on the Big Data principle. Real time data are collected in order to monitor travel demand, the closest driver, estimate journey duration and the final cost (Marr, 2016, p.267).

The term of Big Data includes large amounts of «machine-readable information» collected by mobile devices, credit cards and social media (Offenhuber, 2014, p.7). As the use of these tools is almost an integral part of everyday life, the footprint they leave make the exploration really interesting in order to understand how a society behaves and what it takes at any given moment. Therefore, questions such how big data could promote sustainable city transport need to be answered.

1.3 PROBLEM STATEMENT

It is easily noticed that urban areas show increasing signs of environmental stress caused by rapid motorization in combination with population growth. Apparently, as the human-made space became larger the concentration of transport activity have risen sharply. As a consequence, serious problems such as traffic congestion, traffic accidents or degradation of air quality become evident. It is remarkable how the last decades the whole traffic system was primarily designed for private car use. That, of course, requires space for vehicles and so cities are deprived of this space for other uses during their reconstruction (Persson, 2014). Hence, this suggests the importance of smart growth as opposed to urban sprawl, with a particular focus on efficient distribution of land uses. Smart growth development contributes to the achievement of a less automobile dependent environment. Compact areas with mixed land use, accessibility and livability are part of smart growth policies (Filion & McSpurren, 2017, p.501).

By considering also the interaction between land use and transportation planning (Litman, 2017), the necessity for a sustainable development might be identified with a more compact and resilient urban planning for the future (UN Habitat). Therefore, it is considered necessary to investigate if land use factors are capable to enhance or eliminate automobile dependency as well as commuting by bus, bike or by foot, respectively. For this reason, it is important to explore how various land use factors, such as mixed land use and density are linked to travel behavior within the neighborhoods of Umeå. To investigate the
relationship between build environment and travel behavior, linear regression analysis has
been performed.

To conclude with, this paper focuses on how land use factors concerning population density
and mixed land use affect transport mode choices. It is vital to perceive the reasons that
shape automobile dependency, as well as the reasons that can prevent or force the use of
alternative modes of transportation in order to support sustainability.

1.4 AIM AND RESEARCH QUESTION

The main aim of this paper is to investigate how land use factors such as population
density and mixed land use affect travel behavior. In more details, it is essential to examine
factors affecting automobile dependency and the use of alternative transport modes for
the nine main neighborhoods within Umeå city (Backen, Central City, Erbsoda-Ersmark,
Haga-Sandbacka-Berghem, Marieområdet, Teg-Röbäck, Tomtebo, Västerslätt, Ålidhem-
NUS), as it illustrated in Appendix 4. Additionally, the role of big data in order to succeed
strategic planning and the resulting dilemmas will be discussed.

With this in mind, the main research questions in this thesis have been formulated as:

1. How is urban space with mixed land use (commercial, public service and recreation) and
density linked with automobile dependency?

2. To what extent does mixed-use development and density promote or prevent the use of
sustainable travel modes for commuting?

3. How Big Data Analytics could promote sustainable city transport?

In order to deal with the first two questions two hypothetical scenarios are used in an
attempt to define the relationship between the dependent and independent variables.

Hypothesis

H1: Low population densities in urban and suburban areas tend to increase the levels of
vehicle ownership.

H2: Mixed-use environments contribute to less car dependence. Conversely, mixed-use
development (residential, commercial, and industrial) tend to increase transit and walking.
2. CASE STUDY

Umeå is one of Sweden’s fastest growing cities, known as the City of Birches. In 1888, the city was burned and during reconstruction building birches were used as fire barriers. The University of Umeå established in 1965, doubled the local population and immediately the average age to dropped 38 years old. The expansion of the city is a fact and Umeå participates in common agreements by having a real focus on sustainable development. The design of the build environment is a critical component of improving «accessibility, usefulness and participation». In recent years, the city of Umeå deals with rapid population growth. Urban development challenges try to ensure socio-cultural balance, to promote community participation in decision making and to increase the public satisfaction in public spaces (EGCA, 2018).

As a Nordic region comprises the most densely populated town in northern Sweden. Today, Umeå has extended along the river hosts 120.000 residents. The vision for the future is to reach 200.000 inhabitants, until 2050. The city owns two universities with more than 30,000 students and having also characterized as European Capital of Culture 2014 due to its vibrant culture life. In addition, the Umeå University, consists vital institution for regional prosperity since it occupies 32,000 students and 2,000 researchers that come from all around Sweden and the whole world (EGCA, 2018).

Table 1. Key indicators, Umeå municipality. Source: European Commission, 2016, p.11

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>120,000</td>
<td>Inhabitant</td>
</tr>
<tr>
<td>Area</td>
<td>51 (excluding water)</td>
<td>km²</td>
</tr>
<tr>
<td>Population Density</td>
<td>2331</td>
<td>Inh./km²</td>
</tr>
<tr>
<td>GDP</td>
<td>40,100</td>
<td>€/Capita</td>
</tr>
</tbody>
</table>

A fast growing economy with development strategies designed to improve sustainability. Umea’s ambition is to increase green areas, density and accessibility. Gender equality in public spaces is also a challenge to fulfill thence, local actors are working on that for more than 20 years. New green spaces designed in an effort to increase accessibility while promoting at the same time walkability and cycling. An attempt to enhance the use of alternative transfer modes and support further physical activity, a key determinant of population health (EGCA, 2018).

The increasing population growth, undeniably contributes to environmental degradation, in whatever form, whether it is air, water, land or noise. Air pollution is unfortunately one of the most common causes that are harmful for the environment (Kay; Tyagi, Garg & Paudel, 2014, p.1493). For the reason that Umeå is a fast growing city, it is responsibility of local
actors to prevent environmental risks. As it has been observed increased traffic began to deteriorate air quality and acoustic environment (EGCA, 2018). In order to improve environmental quality and to ensure sustainability the negative effects of vehicular pollution must be taken seriously.

Based on previous research «for every gallon of gasoline manufactured, distributed, and then burned in a vehicle, 25 pounds of carbon dioxide are produced, along with carbon monoxides, sulfur dioxide, nitrogen dioxide, and particulate matter». All these emissions are main sources of greenhouse gas emissions that are responsible for global warming (Marin Donohoe; Tyagi, Garg & Paudel, 2014, p.1493).

Overall, the key goal for the municipality of Umeå is to decrease automobile dependency as well as to promote environmentally sustainable urban transport. In 2014, the use of sustainable urban transport (public transport, cycling or walking) represented only about 50% of the trips while the first goal was to reach the level of 55%. At the present time, the medium-sized city of Umeå has the opportunity to satisfy its aspiration, to peak at least 65% of sustainable urban trips before 2022 (RVU, 2014, p.2).

As it can be seen from Figure 1, the use of private vehicle is the most predominant travel mode on a daily basis. Most trips are marked in Ålidhem/NUS area as well as in the central part of the city. It is remarkable that the most common traffic flow daily occurs between, Ersboda/Ersmark and Haga/Sandbacka/Berghem with the Central city (EGCA, 2018, p.3). In Appendix 4 illustrates the main neighborhoods of the Umeå city.
3. LITERATURE REVIEW

3.1. **Urban stress**

Over the last decades, cities and metropolitan areas due to urban development deal with several problems, such as population growth and urban sprawl that are directly connected with automobile dependency, energy consumption, greenhouse emissions and human health effects (Fan, 2007). Specifically, the European cities are under environmental stress due to transport infrastructure and vehicles that both can cause a landscape to become degraded (Jongman & Kamphorst, 2000, p.16). Stress describes all these impacts caused by contributors such as noise, overcrowding, air pollution and lifestyle-related factors (Evans; Burton, 1990, p.81). All mentioned above support the consideration of sustainable transport as an essential goal.

Naturally, there is a real connection between urban environment and travel behavior. Under certain circumstances, land use development may affect travel behavior, while the adjustment of appropriate transportation policies are capable to promote urban sustainability. Still, transport is fundamental to development but this has to happen by reducing automobile dependency and enhancing sustainable travel modes for commuting (European Environment Agency, 2016).

Undeniably, there is the need for transition from traditional automobile-centered transportation planning to newer techniques designed to support sustainability. Therefore, new sustainability-oriented projects are most needed in order to reduce road capacity. As cities during decades tended to increase the capacity of transportation network, now they are making efforts to recover from traditional automobile-centered development. Subsequently, terms like “road diet” (explicit reduction of road capacity) and “complete streets” would consist plans to prioritize sustainable transport (United Nations, 2010).

Complete streets policy (2013) intention is to ensure safety and accessibility to all users while support walking, cycling and physical activity that have health-beneficial effects on humans. In other words, it helps residents to stay healthy, active, and energetic while ensures environmental sustainability. This policy provide convenience for everyone. Not only is it possible to reduce consumption of fossil fuels, car emissions and traffic congestion that improve air and sound quality, but also it is a way to make the public space safer and the city more vibrant and economically attractive.
3.2. TRANSPORTATION AND HEALTH CONNECTION

Cycling is probably the most sustainable transport mode that promote physical activity. Cycling and walking consist essential components in sustainable transport strategy and previous research suggest that both have several benefits linked with physical and mental health (reducing risk of obesity, cardiovascular and other diseases). Research indicates that «even 30 minutes per day of moderate-intensity physical activity», may have significant health benefits (Pucher et.al., 2010).

As cycling is beneficial to health as well as it consists an environmental-friendly transport solution it is though important to ensure safety from injuries and crashes, in order to increase the rates of bicycling. Actually, regulations in North America oblige children and in some cases adults to use helmets with a view to prevent head injuries while in most of European countries there is no law (Reynolds et.al., 2009, p.2).

On that point it is important to explore how infrastructure should be planned by giving priority to cyclist safety. Previous research demonstrated that roundabouts are safer for cyclists in relation to intersections. But still literature refers the phenomenon of "looked but failed to see" (LBFTS) crash since a part of cyclists are not visible by car drivers (Cumming, 2012, p.2).

3.3. NEW URBANISM AND SMART GROWTH

After that, New Urbanism appears as the new development approach which try to utilize the build environment in a more efficient way. Mixed land use, compact city, connectivity and more walkability, diversity and transit-oriented development are some of the new implementations of urban design intervention (French, 2012).

The New Urbanism is a movement that tries to deal with all those non-functional parts of the current planning system and emphasizes the need for additional changes. For instance, Katz (1994) refers that it is time to rethink about the cons of suburban sprawl and to make a reconstruction of plans based on more compact communities. Suburban sprawl was the cause of the presence of separation in society, a cause of isolation and alienation, as well as a hospitality room for crime.

Nowadays, this movement comes as the new perspective of less automobile urban areas that are focused more on the use of alternative travel modes such as walking, bicycling and public transit. It is an attempt to ensure less automobile travel to work destinations by planning «more compact neighborhoods with grid-like street patterns, mixed land uses, and pedestrian amenities» (Cervero & Radisch, 1996).
According to previous research in metropolitan area of Adelaide in South Australia it is clear that urban planning movements, namely Smart Growth and New Urbanism, consider that single uses and low densities are directly linked with high levels of vehicle ownership (Soltani & Somenahalli, 2005, p.9)

Smart growth is another approach which involves urban development in a more functional and essentially intelligent way that respects the environment and releases the city from its problems. In order to deal with environmental risks within urban space, smart growth suggests measures which increase density levels for residential areas and try to encourage sustainable transport solutions (Filion & McSpurren, 2007).

As it has been observed from previous studies the presence of mixed land use within neighborhood and short destination distances are capable to cause more physical activity in the wider area. As can be seen, urban form in fact defines travel patterns. The most interesting approach to this issue has been proposed by Jane Jacobs in her book The Death and life of Great American Cities (1961). In her attempt to justify the character of a vital urban life, she refers that mixed use, high density and small blocks may motivate residents to walk around (Jacobs, 1961, p.133-143).

Before a decade, in North America spatial planners and local actors introduced the action of Smart Growth in an attempt to plan more compact urban areas and less automobile-oriented. (Filion & McSpurren, 2007, p. 501-502). There are several publications focused on mixed land use. In 1989, Cervero introduced the Entropy Index that describes the degree of mixing in an area. While most authors found connection between entropy scores and walkability, Wineman observed a negative relationship respectively. Further research on this field indicates the acceptance of the Entropy Index as a motivating force behind walkability (Gehrke, 2017, p.67).

Smart Growth initiatives aim to a more affordable transportation system with qualitative services and supportable prices. The cities of tomorrow are outlined as less automobile and therefore with better air quality. Hence, the reduction of car ownership is of major importance while walking, cycling and public transit need strengthening.

3.4. **TDM Measures**

As reported by Friman, Pedersen & Gärling (2012), the use of private vehicles cover residents «needs, desires, and obligations» in order to fulfill their activities in daily life (Friman, Pedersen & Gärling, 2012, p.5). This tendency, of course, should not be prevented, but any harmful consequences could be eased by appropriate configurations. Nowadays, due to environmental risks transport policy measures are necessary to urban areas.
For that reason Transportation Demand Management (TDM) has been introduced in order to deal with transportation issues. TDM refers to complementary measures created to fill potential planning gaps. Usually, include measures to address traffic congestion and environmental pollution problems as well as cost and safety issues (Litman, 2013, p.245).

The way policy measures are applying appear as diverged from previous decades. With a closer look back to 60s it is obvious how policy measures were mainly oriented into road infrastructure while the next decade most of attention was on improving the existing road network. New trends in policy making affect the general perspective of transportation and mobility within cities and from 80s the focal point are agents that affect travel behavior (Friman, Pedersen & Gärling, 2012, p.8). Over time and the evolution of technology, the new direction shows the use of data to better exploit and operate modern cities. In recent times TDM planning is based on digital data (‘Big Data’) (Litman, 2013, p.245).

3.5. **BIG DATA ANALYTICS**

Computational social science is the connection between social science and computer science. (Lazer et. al.; Offenhuber, 2014, p.7). The Computational social science in combination with Network science treat the urban space as an entity with connected objects. As objects could be characterized social phenomena that develop in space. In order to explore relationships and interactions that are evolving in space, urban informatics introduced by incorporating new technologies into urban space (Forth; Offenhuber, 2014, p.8). By this way, with the use of sensors and Global Positioning System (GPS) make it possible to collect data for management and interpretation afterwards (Offenhuber, 2014, p.8).

A common example is the use of photo-sharing websites where photos with geotags are uploaded from users. Therefore, by sharing real-time location it is easy to investigate travel options and to exceed results about travel behavior of a target group (Offenhuber, 2014, p.10). So it is clear the interaction between urban real data and urban infrastructure. Apple and Google store are the most well-known data collectors based on the behavior of users in space recorded in big database (Offenhuber, 2014, p.11-14).

The term of Big Data (BD) refers to huge volume of data, based on Information and Communication Technologies (ICT), and which through appropriate collection, management and analysis can deliver results to support effective and functioning smart cities (Osman, Elragal & Bergvall-Kåreborn, 2017).
3.6. **Big Data Analytics for Transportation**

The rapid growth of technology makes it possible to collect data through the use of social networks, smart phones, tablets, GPS devices, sensors, log files, and many other devices. By this way it is easy to improve the functionality of the city by analyzing and monitoring complex data collected from devices. Data complexity can be described as the 4Vs (Volume, Velocity, Variety and Veracity) due to high size, collection speed, diversity and uncertainty of data respectively (Ben Ayed, Ben Halima & Alimi, 2015, p.311).

Today, the main challenge is to deal with all these data. Big Data Analytics by collecting information captured from roads and vehicles sensors, GPS and personal devices are capable to improve transportation system, reduce the costs and support decision making for better planning. Several smart cities have incorporated Big Data Analytics as a smart tool for more efficient organization.

India developed a project with the use of Big Data Analytics and Apache Hadoop (open-source framework) where data such as fuel, speed and GPS traces are collected as packets to Hadoop servers. Through periodic data analysis, aims to improve the transportation system and to reduce costs. So, by monitoring travel patterns it is easy to prevent risks and to control fuel consumption (Ben Ayed, Ben Halima & Alimi, 2015, p.313).

The smart city of Dublin, in an effort to reduce traffic congestion and to improve the public bus services, developed a project based on GPS data collected from bus devices. As a results, travel patterns are capable to be managed in order to prevent anomalies within the city. Future vision for this project is to incorporate also meteorological data (Ben Ayed, Ben Halima & Alimi, 2015, p.313).

Correspondingly, the city of Stockholm consists another case where Big Data Analytics have been used to support a real-time intelligent transportation system. Taxis and other vehicles were supplied with GPS devices hence, data collected combined with weather information try to predict mobility within the city (Ben Ayed, Ben Halima & Alimi, 2015, p.313).

3.7. **Intelligent Sustainable Liveable Cities**

According to UN report, almost 54 per cent of the world's population lives in urban areas, while it is estimated to reach at 66 per cent by 2050. Markedly, there will be another 2.5 billion people that is going to be added in the present urban population. Of course, there is no doubt about the rise of urbanization. By looking back in 1950, it is easy to perceive that the picture has been different, since the total urban population was around 746 million. An amount which until 2014 has been increased to 3.9 billion (United Nations, 2014).
Today, the trend toward urbanization continues to grow, therefore a more efficient planning based on new technologies is needed. Urbanization problems due to rapid population growth require the concept of the Smart City (SC) as a new approach in order to improve the quality of life and increase sustainability in the urban landscape (Osman, Elragal & Bergvall-Kåreborn, 2017).

As Smart City can be defined the appropriate strategy which is applicable in urban space by using technology. The main aim of this approach, with a real focus on technology challenges, attempts to develop communities and to deal with severe problems such as traffic, pollution, energy consumption, waste treatment. (Monzon, 2015, p.19-20)

Liveable Neighbourhoods refers to the new structure plan where the spatial structure of neighborhoods acquires a more compact design with appropriate road network, connectivity and intersection control (Western Australian Planning Commission, 2000).

In recent years city planners, developers and policymakers are more orientated towards designing more compact neighborhoods. Short distances in an urban planning is considered more eco-friendly as residents live closer to amenities. Consequently, pollutant emissions as well as energy consumption seem to be confined to a compact city form (Banister et. al.; Thomas et. al., 2010, p.254). In contrast with lower densities, quality of life and better interaction may be achieved (Bramley et. al.; Thomas et. al., 2010, p.254). As it has been shown, high density is usually associated with problems such as environmental degradation due to congestion, pollutant emissions and noise, as well as low human interaction (Howley et. al.; Thomas et. al., 2010, p.254).

In modern times, most European cities appear a multicultural mosaic due to increasing international migratory flows. Phenomena such as racism and social segregation pose serious urban problems that affect the security and functionality of the cities. That is why it is necessary to use the new technologies in the city network, which is as important as the transport infrastructure. With the proper use of communications, citizens can create social networks within the city more easily and thus integrate much smootherly into each

Figure 2: Clustering of neighborhoods, Source: WAPC, 2015, p.14
new environment. Improvement of both transport and communications infrastructure can create an interactive network within the city where all citizens can have easy and fast access. With active participation and equal access to all, all traces of social exclusion are eliminated, while security and trust are ensured (Chivot, 2011, p.62-63).

According to the Western Australian Planning Commission, compact urban areas that are mainly planned as walkable neighborhoods surrounded by mixed land use, consist part of the recent operational policy for the design of the future development. As the DRAFT 2015 refers «Planning of an urban structure is focused on clusters of compact and well-defined walkable neighborhoods and activity centers» (WAPC, 2015).

Focusing on this draft, urban structure consists of walkable neighborhoods defined as circles within 400 meter radius (approximately 50 hectares) that has directly accessibility within five minutes’ walk. A distance of no more than 400 meter accessibility to services and 800 meter to train station encourages residents to walk. As a result, the final aim is approximately 60 per cent of residents to live in a 400 meter from an activity center or public transit stop. It is has been proved that well-connected neighborhoods with interconnected streets and mixed land use increase the accessibility between these areas that boost physical activity (WAPC, 2015).

3.8. **TRANSIT ORIENTED DEVELOPMENT (TOD) AND BUS RAPID TRANSIT (BRT) SYSTEMS**

Cities in order to deal with rapid urbanization try to develop Transit Oriented Development (TOD) strategies. TOD refers to mixed land use development in an effort to locate amenities close to people. As a result, the use of alternative transport modes can be increased while automobile dependence appear to decline (Carlton ; Sahu, 2018, p.467). As TOD neighborhood can be defined a mixed land use area (residential, commercial, industrial), where residents can perform their daily activities within close proximity of their residence and with the choice of alternative modes of transportation (MoUD ; Sahu, 2018, p.467).

The general picture of the contemporary city is usually connected with the presence of traffic congestion which seems to degrade the quality of air, affect noise level and by the same token the smooth provision of services is impeded. Bus Rapid Transit (BRT) appear as the new sustainable trend that contributes on efficient development in regards to transport infrastructure. Based on research studies, metro and rail infrastructure often can cost more than 10 times or 4 times respectively, in relation to BRT system. But except the cost matters another important point is that BTR seems as more flexible with high-capacity transit (Suzuki, Cervero & Iuchi, 2013, p.9).
Land use factors are capable to define the transportation options within the city. Sustainability in transport modes can be succeeded as it has been proved through compact mixed land use planning. BRT appear as a cost-effective and ecofriendly solution especially for huge and motorized urban centers globally (Suzuki, Cervero & Iuchi, 2013, p.113-114).

Spatial planners should consider more about the connection between the shape of the city, the neighborhood or the society and the effects on travel behavior for its residents. In other words, an emphasis should be pointed on mixed land use and high density areas that are capable to promote physical activity (Boer et. al.; Gehrke, 2017, p.11). Furthermore, a planning system based on details in regards to concentration of different land use such as commercial, residential and industrial areas in combination with an efficient multi modal urban network may provide sustainability and creates an attractive city illustration (Cervero & Duncan; Gehrke, 2017, p.11).

However, as cities consist the core for human and economic activities there is a real challenge through development to improve the life quality of their inhabitants. The use of new technology can contribute directly and effectively support every effort for sustainable development. With the use of big data applications, it is easier to visualize and analyze the data recorded daily and provide extra information about people’s travel behaviors. According to previous surveys, the data resulting from the use of smart cards in the BRT, reveal citizens’ travel attitudes on a daily basis. Thus, by investigating and understanding the needs of a city, it is possible to develop the appropriate transportation network to serve the inhabitants in a more efficient and ecological way (Tao et. al., 2014, p.91).
4. THEORETICAL FRAMEWORK

«Cities should respect nature, consider the urban ecological environment as an asset, integrate environmental issues into urban planning and administration, and accelerate the transition to sustainable development».

Shanghai Declaration on Better Cities, Better Life

4.1. BUILD ENVIRONMENT AND ACTIVITY SPACE

Generally, the amount of travels in Sweden has increased sharply through time. Particularly, the total distance for travelling has been accompanied by a correspondingly sharp increase of private cars. From 55.764 million on vehicle-kms in 1990 to 58.895 million on vehicle-kms in 2000 and finally to 67.355 million on vehicle-kms in 2016 (Swedish Transport Administration, 2017). For the reason that travel contributes to risks such as congestion and pollution, appropriate measurement and evaluation are critical for policymakers.

Hence, new ideas into policy-making are needed for urban planning that cope with more sustainable solutions in urban landscape. The New Urbanism movement in the United States and the Compact City Policy in Europe appear with main goal to reduce the use of private vehicles and travel distances (Acker & Witlox, 2009, p.1).

In the literature, several theories have been proposed to explain the role of high-density and mixed-use neighborhoods with shorter and non-motorized trips. The conclusion is that there is relationship between land use and travel behavior. The latter is usually connected to socio-economic factors as well as psychological characteristics related to lifestyle (Acker & Witlox, 2009, p.2).

In the literature, several theories have been proposed to explain the relationship between built environment and travel behavior. Ewing & Cervero (2001) argue that the built environment and socioeconomics consist critical factors that define travel mode choice. Reynolds et.al. (2009) refers also that «the built environment has been implicated as an important determinant of bicycling rate, but these relationships are complex and a positive correlation has not always been found». As it concerns walkability within neighborhoods there is another approach connected to built environment. Existing research describes the concept of 3Ds (population Density, land use Diversity, and pedestrian-friendly Design) characteristics (Yamada et. al., 2012). Similarly, have proposed how travel demand depends from density, diversity, design, and regional accessibility. All mentioned previously consist measurements of land-use, transportation, and environmental characteristics within a
neighborhood area and are incorporated into Smart Growth Index (SGI) (Criterion Planners/Engineers Inc, 2002).

4.2. THEORY OF MIXED LAND-USE

As mixed land-use consider the «overall built environment» divided by the most common use type within neighborhood areas, such as residential, commercial, industrial and institutional. It has been observed that travel behavior can be affected by the formation of the surrounding environment (Cervero, 1991, p.480).

Smart growth policies consider the incorporation of mixed land use as an indispensable tool for urban planning and promotion of public health (Gehrke, 2017). The notion of land-use mix appear as the locomotive force which urges travel behavior. At the same time it refers to some presence of diversity within space (Bordoloi, 2013, p563). The way in which land uses are distributed in space seems to define travel routes. It has been proved that the more presence of mixed land use the more trips may occur (Cervero, 1991, p.479-480). Previous research from Canada and Scandinavia indicate that mixed land use in combination with functional public transportation options, may favor mass transit for suburban workers and residents (Cervero, 1991, p.491). For several years, great effort has been devoted to the study of land use mix and it has been revealed, its influence on transport mode choice as well as the length of trips (Bordoloi, 2013, p564).

As it has been proved, land use mix and socioeconomic characteristics are directly connected with residents travel behavior. The choice of transport modes and trip lengths are defined from residents desire to reach a particular destination. This kind of desire seems to be defined from the distribution of points of interest (POI) in space. In the research fields, several theories have been proposed to explain the connectivity between land-use and travel behavior. Cervero (1991) argues that low densities, single uses, small scales and plethora of parking lots consist factors that contribute to increasing automobile dependency in suburban areas. On contrary, regions with high density, mixed land use and limited parking areas seems to enhance walkability and promote the use of alternative transit modes (Cervero, 1991, p.479-480).

Research implies that mixed land use appear to be directly connected with the automobile dependency. Furthermore, the assumption that it also affects the use of public transportation is almost certainly correct. That occurs from the fact that the public transportation consists that mode for residents to fulfill their needs for activities, such as working or shopping. There is undoubtedly a direct connection between land use mix and travel behavior. The way the land is distributed out of its uses seems to contribute on how many trips will occur inside a specific area. In order to measure the level of mixed land use in each area, the entropy index has been introduced. Studies indicate that this index is more appropriate to estimate the form of mixed land use especially in small urban centers.
Correspondingly, analysis based on socioeconomic characteristics in combination with the understanding of the role of mixed land use may provide clues about residents travel behavior (Bordoloi, 2013, p564).

For many decades mixed land use seems to encourage residents to walk to the wider area of their residence, but this will soon change after the implementation of Euklidian zoning (Brown et.al., 2009). This implementation aimed to separate the residential area from the industrial one to the benefit of public health, but soon severe consequences identified such as urban sprawl and extended single-uses within neighborhoods. As a result, it brings disparities of income, social exclusion, increased urban footprint and high levels of automobile dependency (French, 2012). In addition, it is related to health problems caused by low physical activity associated also with obesity and pollutant emissions by vehicles (Booth et.al.; Brown et al., 2009, p.1130).

4.3. **AUTOMOBILE DEPENDENCY AND URBAN ENVIRONMENT**

The implementation of policies are of major importance for cities as they regulate socioeconomic activities while also having environmental impacts. A challenge for the cities of tomorrow is to facilitate sustainable development of transport system. Appropriate policies are capable to define transport options and with efficient land use development to direct travel behaviors. The challenge of making transport sustainable is directly linked to automobile dependency, which in turn is defined by transport and land use patterns. Of course, the main objective is not to eliminate vehicles in the city but to ensure alternative modes of transport that promote sustainability and support the ability of non-motorized travel (Kodukula, 2011).

Previous research has documented how density and socioeconomic factors have impact on travel behavior. Especially, high density and mixed land use appear to contribute to lower levels of vehicle ownership. In recent decades cities seek how to better manage urban sprawl and environmental risks. It is very common that metropolitan areas have a polycentric character usually with a business center surrounded by smaller commercial centers. Nowadays, the polycentric character of urban regions have been built to accommodate commuter flows, as opposed to the traditional monocentric model of the past (Hamilton; Vasanen, 2013). As a result, urban sprawl create low-density areas with more automobile dependency in the periphery of the central town (Litman, 2017, p.10).

Research also suggest that land use development patterns may affect the usability of a city. It could also be noted that wealth does not alone explain the level of automobile dependency within city. Undoubtedly, as mentioned previously high density in urban areas seems to be responsible for lower vehicle ownership and more intense use of public transport. Respectively, the higher the urban density in an area, the more intense the use of non-motorized modes become (Kenworthy & Laube, 1999, p. 719).
The term of automobile dependency usually appears to be directly linked to cities or areas that are wealthy. But if we investigate further we will perceive how the situation is totally different in European cities. It seems that several developed countries in Europe and Asia have incorporated less automobile dependence in their urban design. On the other hand US cities seems to have the higher dependence on the automobile (Kenworthy & Laube, 1999, p. 718). Of course the use of private vehicles in the city described as an «Irresistible Force» but it is true that part of Australian, Canadian, European and wealthy Asian cities make efforts in order to decline these automobile dependence patterns (Lave, 1992, p. 10).

Therefore, it is noticeable how the planning system for transportation through appropriate policies and land use factors may affect travel behavior. Particularly, in case of reducing vehicle operating costs, travel times or the risk of vehicle use then there is automatically an increase in car dependence which eventually leads to traffic congestion and sprawl. On the contrary, when development is supported by efficient public transportation and alternative non-motorized options at lower costs then, the smart growth principles are established (Litman, 2017, p.11).

It is noteworthy that when land use patterns favor mobility or accessibility then the degree of automobile dependence tends to decline. In fact, urban form can be seen as a button that trigger flows around the city. Moreover, high road and parking capacity seem to limit the availability of land for further activities. As a result, cities cannot benefit from accessibility, while the high levels of automobile dependency do not leave enough space for alternative transport modes to rise (Litman, 2017, p.11).

On the other hand, it is clear that those cities designed with a small road network face problems of traffic congestion. When the road capacity is small, the traffic flows follow secondary roads that are not designed to host high levels of traffic. By this way these roads are not anymore available for alternative activities since the overall environment becomes unsafe due to accidents and pollution (Elvik et.al., 2009, p.172).

Therefore in the final analysis, it is vital to ensure an appropriate neighborhood design, based on mixed land use that would support walkability as well as the use of alternative transport modes, but at the same time without excluding vehicles. With the proper neighborhood planning and by increasing transportation sustainability, the city would gain by reducing automobile trips and travel distance, while would ensure less air pollution and generally provide a better quality of life. With a mixed land use design it is possible for neighborhoods to reduce automobile dependence since the residents have opportunity to work, shop and interact in the wider area of their residence (Santa Barbara County, 2010).
4.4. **SMART CITY - URBANIZATION**

The urbanization trends of the urban and suburban space have increased exponentially the demand on infrastructure. The shape of the city is changing following social change and the evolution of technology. Cities consist significant factors of the global economy, so it is important to achieve continuous development by dealing with environmental issues and it is vital to ensure sustainability (Ramaprasad, Sánchez-Ortiz & Syn, 2017, p.13).

Technology is changing this world at an astonishing pace which commands the need of a better quality of life. As reported by Williamson «a smart city needs to be spatially enabled», which means that the physical and social infrastructure should be available to everyone (Williamson et. al.; Rose, 2014, p.708). The term of Smart City includes all these initiatives for urban development based on Information and Communication Technologies (ICT) (Osman, Elragal & Bergvall-Kåreborn, 2017).

Smart cities can be seen as biological microorganisms. It seems like evolving, developing, recreating and leading to new conditions for the inhabitants. However, like any organism affected by environmental conditions. With the increasing use of technology, these cities acquire a new identity that belongs to the modern world and needs a smarter character.

4.5. **URBANIZATION AND MOBILITY**

The cities of tomorrow will have to face the overpopulation phenomenon. The 2015 Revision from United Nations presents a generous prediction of the future world population. The estimations reveals the population growth that seems to be increased to 8.9 billion inhabitants on 2030, to 9.7 billion on 2050 until it reaches to 11.2 inhabitants on 2100 (United Nations, 2017).

Population growth and the rapid urbanization lead governments, local stakeholders and planners to take action in an effort to prevent intensive effects of traffic congestions, air pollution, energy consumption and several other problems that are concentrated in spatially limited urban areas (Alawadhi et. al., 2012, p.40).

Urbanization is the motivation power for mobility and as the population growth tend to be increased during decades the need for more space rises. In the beginning of 21st century, population mobility estimates around 8 billion trips daily where half of them are made by private vehicles. Projections reveal that until 2050, the number of commuters will raise three to four times compared to 2000 (International Transportation Forum ; Cervero, 2013, p.2).
Nowadays, the need of a more sustainable transportation system, based more on public transit and less on automobile-dependency constitutes the new challenge for future cities (Gakenheimer & Dimitriou; Cervero, 2013, p.2). Also decision-makers in developing countries need to take into consideration the ever-growing population, the rising mobility and furthermore to face the impacts of climate change. Climate change affects a variety of factors, therefore it is vital to ensure a climate-resilient urban transportation system. In fact, the transport sector appear to be directly associate to climate change, since it seems to be responsible for producing 23% of total energy-related CO2 emissions (International Energy Agency; Cervero, 2013, p.2). Thus, this reflects the necessity for investment to lower-carbon transportation system which is capable to ensure resilient smart cities with good quality of life for their citizens. This could be succeeded by finding more efficient vehicles and policies, reducing trips by densifying urban landscapes and creating mixed land-use, utilizing advanced information and communication technologies (ICT) for a smart multi-modal transportation system, and also to make public transportation, walking, cycling more attractive for commuters (Sims et. al. 2014, p.603).

As the transportation system is embedded within the cities, one could argue about its significant impact on economic growth. Undoubtedly, it consists an important factor that affects social development as well as it is responsible for potential environmental impacts (Cervero, 2013, p.1).

Therefore, it is essential to create more resilient cities by promoting more sustainable transport modes for commuting. In recent years, this has been the subject of considerable debate in an effort to promote the use of public transport and reduce car use. Additionally, it is essential to recognize that there is a real challenge for spatial planners to reconstruct the cities with a more efficient and functional way. Until recently, city’s plans and investments in transportation were focused more on covering mobility, while there is evidence that the formation of urban space is the key for sustainability in infrastructure. It is worth noting that based on new perspectives, compact and mixed-use development and transit-orientated development (TOD) are aspects that could give lot of impetus for more functional cities (Cervero, 2013, p.1). Furthermore, it is a common belief how the use of big data analytics may contribute to smarten up cities and to improve its transportation system.
5. METHODOLOGY

The methodology of this research is based on quantitative approach. In this chapter, the research methods are described, as well as the way in which all the necessary data have been collected and utilized mentioned. Based on secondary data analysis a question-driven research has been executed. By creating various hypothetical scenarios effort is being made to analyze the data in order to answer the primary questions.

Then, the analysis process follows, based on statistical methods and regression analysis. Primary and secondary data have been used. Data was collected electronically from online statistical databases. Finally, geospatial processing software will be used in order to visualize the geospatial data.

5.1. DATA COLLECTION AND SOURCES

First of all, a key piece of data used in this survey is based on evidence from a survey conducted in 2014 by the Umeå municipality (Umeå Municipality, 2014). The main focus of this survey was about to investigate travel habits and choices of transport for residents within the city. Therefore, the data gathered relates only to the neighborhoods of Umeå.

In 2014, travel survey known as Resvanor i Umeå (RVU) survey conducted by the municipality of Umeå in order to investigate residents travel habits. During the survey, 5,528 inhabitants in ages of 16-84 have been interviewed. The overall survey consisted partly of travel diaries and partly on background issues about age, sex, employment, driving license holdings, access on transportation, general travel habits and a matter of attitudes to different modes of travel. In the travel diary, respondents would describe their travels on a chosen weekday in week 41. Those who had not responded within about 10 days received a brand new survey with new cover letter and answer envelope and new measurement day (same weekday as before but in week 43). Those who did not answer this questionnaire were now tried by telephone and then spoke verbally for their traveling corresponding weekday in week 45. In total, the survey reached 5,424 people. An amount of 2,288 people answered the questionnaire and another 467 people were interviewed by telephone. As a result, a total of 2,757 people participated in the survey and the travel survey response rate was 50.8%. This was a lower response rate than at the survey in 2006, but higher than in many other travel surveys carried out in other municipalities in recent years (Umeå Municipality, 2014).
The information that have been selected from 2014 RVU survey relate to the rates of car, bus, and bicycle use, walking rates, trip rates as well as the number of work trips of shopping trips. Additionally, data selected from Sweden Statistics (SCB) and from the online database of Umeå municipality. These data refer to population, income, sex and educated population.

It is worth noting that in terms of data collection there were some difficulties in the beginning as there was no access to microdata as requested. The basic file it needed was a shapefile of Registered Cars by SAMS. From Statistics Sweden the cost for ordering one table by grid square was really high while at the same time there was no permission to access the ASTRIS database of the Umeå University. Finally, an excel file was taken from Transport Analysis containing the ownership of cars per SAMS area code (2011-2016), which joined with the corresponding shapefile recovered from the online database of Lantmäteriet.

From the government agency known as Transport Analysis, have been received data concerning car ownership levels for each neighborhood in Umeå. The statistics is an average over the years 2011-2016, as a result from the national travel survey. A file named Number of cars per sams-area in Umeå municipality was received as an excel document. At this point, it should be noted that there is a kind of uncertainty in relation to the numbers of this research, as it is based on a small sample of 386 people. However, the results were compared with data from the Umeå municipality’s statistical database, and the difference seems to have a range if ± 1,000 cars except from the case of Teg’s neighborhood where the situation seems to have been very much overestimated. The reason why data was selected from the Transport Analysis rather than from the municipality, is that in the first case the survey data are structured based on the sams regions and can be possible then be visualized on a map. On the contrary, the municipality has only the statistical numbers for the general urban areas and thus it was not possible to use them further.

Another data source is the national organization of Lantmäteriet, which through the online database of Geodata Portal (geodata.se) provided access to spatial data and specifically to Small Areas for Market Statistics (SAMS). Geospatial data and orthophotos collected. In fact, files used in this research are the SAMS shapefiles of A9: Population 25-64 years by education level for the year of 2015, B10: Population change for the year of 2015 and IH1: Household age 20 and above by purchasing power for the year of 2014, respectively (SCB, 2016). Additionally, it has been received SAMS shapefile of IF3: Familjer 20+ år efter disponibel inkomst for the year of 2012 and orthophoto GSD-Ortofoto for the year of 2015 (Lantmäteriet, 2015). Another shapefile that found as GSD-Fastighetskartan, vector has been used concerns the buildings in the Real Estate Register Building Section defined according to the Planning and Building Act (PBL 2010: 900), (Lantmäteriet, 2017).
The aforementioned data was adapted to a shapefile file which depicts the SAMS areas. Thus, the main 9 neighborhoods within the city (Backen, Central City, Erbsoda-Ersmark, Haga-Sandbacka-Berghem, Marieområdet, Teg, Tomtebo, Västerslätt, and Ålidhem-NUS) are subdivided into 59 smaller areas known as SAMS-areas.

By using the file GSD-Fastighetskartan, all buildings have been aggregated in ArcMap 10.3, so each construction was classified based on its use, defined by residential, commercial or industrial use respectively. Then, the tool of Multiple Ring Buffer has been used in an attempt to create a buffer zone with 5 meters radius around each feature. As a result, a new shapefile has been created which indicates the overall developed area for every SAMS area.

The final shapefile consists a compilation of data gathered previously, where each SAMS area defined by its code id. Each code corresponds to plethora of information covering from the socio-economic situation of each area to the uses of the buildings.

5.2. **Quantitative Approach**

This paper utilizes a research that can be described as quantitative approach. Quantitative approach can be briefly described as data analysis based on data collected previously so that can be analyzed in terms of numbers (Babbie, 2010).

An important point to note is that statistical methodology is divided into descriptive statistics and inferential statistics. Descriptive statistics refers to the summary and brief description of a data set, while inferential statistics is the generalization process from which exporting knowledge by examining just a part of the sample (Burt, Barber & Rigby, 2009, p.4).

In this case the use of descriptive statistics will be used in order to visualize how the collection of data represents specific neighborhoods with the city. Additionally, inferential statistics will provide further information about travel behavior of residents represented by a random sample of previous survey.

5.3. **Entropy Index**

Land cover analysis is a process which is usually described as qualitative. In an attempt to analyze the land cover variations, a quantitative analysis was necessary. Consequently, Shannon’s diversity index was used in an attempt to estimate landscape diversity. In 1948, the father of information theory, Claude Elwood Shannon, introduced the Shannon’s diversity index equation which is also known as Entropy Index (Dušek & Popelková, 2012, p.5-6).
In this study, the Entropy Index has been used, in order to estimate the levels of mixed land-use present within the neighborhoods of Umeå city. The index refers to landscape metrics which reveal by numbers, if there is presence of homogeneity or heterogeneity in land uses. This will be calculated for every SAMS area based on three different land coverings (residential, commercial, industrial). So for this case, the Entropy Index seems as the appropriate way to estimate the level of mixed land uses for every specific geographic area lies in the city. As it has been analyzed in previous research it is a «pattern of combination and segregation of different land uses» (Bahadure & Kotharkar, 2015, p.12172).

The next equation is depicted as the general form of the Entropy Index:

\[
\text{Entropy Index} = (-1) \times \sum_j P_j \ln(P_j) / \ln(j) \quad (1)
\]

Equation 1. Entropy mix. Source: Cervero; Bahadure and Kotharkar, 2015

where, \(P_j\) is the proportion of developed land in the \(J\)th land-use type. Entropy index varies between 0 and 1, wherein 0 indicates single use described as homogeneity and 1 maximum land-use mix that describes heterogeneity.

Correspondingly, the equation (1) has been formulated with focus on three-category mix (residential, commercial, and industrial):

\[
\text{Landuse Mix Entropy Index (EI)} = (-1) \times \frac{\left(\frac{b_1}{a}\right) \cdot \ln\left(\frac{b_1}{a}\right) + \left(\frac{b_2}{a}\right) \cdot \ln\left(\frac{b_2}{a}\right) + \left(\frac{b_3}{a}\right) \cdot \ln\left(\frac{b_3}{a}\right)}{\ln(n)} \quad (2)
\]

Equation 2. Landuse Mix Entropy Index. Source: Cervero; Bahadure and Kotharkar, 2015

where, \(a\) is the total area in hectares of the three land uses, \(b_1\) is the residential land-use area in hectares, \(b_2\) is the commercial land-use area in hectares, \(b_3\) is the industrial land-use area in hectares, while \(n\) is the total number of land uses in the mix 2 or 3 respectively (Cervero; Bahadure & Kotharkar, 2015, p. 12172).

5.4. **Statistical analysis**

On the next step it is interesting to investigate the socio-economic situation of each neighborhood within the city. This is accomplished with the use of statistical analysis where the most significant information will be presented in a table or a graph. As Burt (2009) argues the statistical analysis expresses the connection between data and information.

In this case two different statistical methods will be used. First, descriptive statistics describes the method which data are numerically or graphically visualized. Then, inferential
statistics will contribute to study of travel preferences through a selected sample of the local population as shown by a previous survey (Burt, Barber & Rigby, 2009, p.32-33).

5.5. Pairwise Correlation and Regression Analysis

To continue with this study it is important to run statistical experiments in order to investigate the type of relationship and interdependence between the variables. Pairwise correlation through the coefficients reveals the strength of the linear relationship between selected variables. Hence, with the use of correlation analysis has been evaluated the relationship between variables and then checked if they are statistically significant at a specific confidence interval with a p-value (p < .05). So, in this case the significance level is 0.05, which corresponds to a confidence level of 95%.

By the same way, the linear regression analysis allow us to examine the relationship between variables. So, four different regression model will be constructed which investigate the connection between socioeconomics and land use planning options.

5.6. Geospatial Analysis

At the end of the survey the necessary maps were designed with the software package of Arcmap 10. Spatial data turned into maps which disclose the distribution of land uses, population density, entropy and vehicle ownership per 1000 residents. It should be noted that the primary data with shapefile (.shp) format had already SWEREF99 TM as coordinate system (projection). Thus, the selected orthophotos have been subsequently geo-referenced based on the same projection.

5.7. Ethical Considerations

As Bryman (2008) refers it is vital to protect the identity of participants and to avoid any kind of invasion of privacy and deception. All findings in this research presented in a way so that individuals not can be identified. Based on ethics this study has as only aim to contribute to knowledge in order improve the quality of human existence. Every step in this research is built on honesty and transparency.

The new challenges for cities are sustainability, social cohesion, smartness. At a time when the rapid evolution of technology have direct impact on society and individuals, it is really critical to establish ethical rules in order to ensure the balance in the future. It is important
to note that the purpose of this research is to observe the needs of citizens with the sole aim of improving the quality of their life.

According to global challenges, it is essential to ensure environmental and social sustainability in an attempt to protect humanity. Undeniably, the urban landscape sustainability is as necessary as the use of technology. Although, it is vital to combine consciousness with the use of new technologies in order to protect human rights and to ensure safety. At the other end of the scale, technology-related things seem to contain intense concerns over ethical dilemmas. Beer (2017), referred to this issues as «The social power of algorithms» where he explains whether an algorithm can exist as a simple code, and whether it can incorporate the concept of social consciousness (Beer, 2007, p.10).

Generally, there is an obvious hesitation of scientists from dealing with algorithms exclusively because of the absence of human consciousness. On the contrary, Meehl argues that «it is unethical to rely on intuitive judgments for important decisions if an algorithm is available that will make fewer mistakes». Kahneman also refers that algorithms are often more capable than people in decision-making, but there are problems that pose moral dilemmas in decision-making. As he declares losing a child’s life by human error is socially more acceptable than the assumption that it came from a mechanical error (Kahneman, 2012).

To conclude with, the use of big data can provide cities with flexibility through smart technology that deeply affect the quality of citizens from every aspect. However, with all the consequences, it must be taken into account dilemmas that has to do with security and privacy matters.
6. RESULTS

This chapter will present the results from statistical analysis. This part concerns exclusively, the demarcation of distribution of land uses within neighborhoods and the observation of the citizens’ travel behavior within the city of Umeå.

6.1. POPULATION STATISTICS

Population statistics show that population size in the municipality of Umeå is around 122,892 residents as estimated for the year of 2016/2017. It is remarkable that the last 5 years in Umeå it has been observed an increase of approximately 1,100 new residents per year. By 2028 population growth is projected to reach the level of 143,536 residents respectively (Umeå Municipality, 2017).

Therefore, according to the most recent estimates, the population size is not expected to result in an extreme rising at least until 2028. However, the construction of new dwellings includes approximately 15,000 planned houses, corresponding to at least 25,600 additional inhabitants for the municipality of Umeå. This naturally is going to impact both density and the urban spatial structure. These new constructions are meant to host families and couples that are intended to have children (Umeå Municipality, 2017).

On the Table 2 below illustrates the forecast of the total population for the years of 2016, 2021 and 2028 respectively in every region of the Umeå municipality. In several regions there is an increase in the population. The regions with the highest growth seem to be Teg, Tomtebo, the central Umeå and the University area.

Table 2. 2016-2028 Population forecast of Umeå Municipality by age. Source: Umeå Municipality, 2017
On 2014, the municipality of Umeå performed a survey (Umeå Municipality, 2014) of 2800 individuals between 16-84 years old. The survey based on resident’s daily trip routines and their travel modes preferences. The results seems to correspond in reality in reference to residents habits.

### 6.2. **Entropy Index values**

The entropy score as a measure of diversity has been estimated for every neighborhood within the city Umeå. Entropy scores for each neighborhood presented in Appendix 3. Correspondingly, Table 3 to Table 4 below, reveal that there is no equal distribution of land uses (residential, commercial, industrial) within the neighborhoods. Map in the Appendix 4 illustrates land mixed use within neighborhoods.

Table 3 reveals that Centrum Västra is the most heterogenous area in regards to its land use mix. Then Berghem Södra area follows and then come the areas of Västerslätt, Centrum Östra, Backen, Haga Norra and Centrum respectively.

<table>
<thead>
<tr>
<th>SAMS Name</th>
<th>Centrum</th>
<th>Haga Norra</th>
<th>Backen</th>
<th>Centrum Östra</th>
<th>Västerslätt</th>
<th>Berghem Södra</th>
<th>Centrum Västra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entropy Index</td>
<td>0.29</td>
<td>0.31</td>
<td>0.31</td>
<td>0.31</td>
<td>0.32</td>
<td>0.34</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Table 4. Lowest levels of Entropy Index by SAMSAREA and SAMSCODE

<table>
<thead>
<tr>
<th>SAMS Name</th>
<th>Röbück</th>
<th>Sandabrånet</th>
<th>Ersmark</th>
<th>Östra Ersboda</th>
<th>Universitetsområdet</th>
<th>Kronoparken</th>
<th>Sofiehem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entropy Index</td>
<td>0.04</td>
<td>0.06</td>
<td>0.07</td>
<td>0.10</td>
<td>0.11</td>
<td>0.12</td>
<td>0.12</td>
</tr>
</tbody>
</table>

According to Table 4, the area of Röback appear to have the lowest Entropy value. By observing values on both tables above can be concluded that there are numerous areas with presence of homogeneity concerning their land use. Generally, it seems that there is not big intensity in mixed land use between Umeå SAMS areas.

Nevertheless, it should be noted that this research is mainly focused on the horizontal land cover without taking into consideration the vertical use of each floor in every building. This would be an in-depth research as a continuation of this study, but this time with a focus on the information of each building.
6.3. **DESCRIPTIVE STATISTICS ABOUT URBAN POPULATION IN UMEÅ**

The next step is to use descriptive statistics in order to summarize and represent the basic socioeconomic characteristics of each area.

Table 5 below reveals the average values of Car Ownership, Total Population, Households over 20 years old, Educated population 25-64 and Parking availability. Respectively, for each category has been calculated sum values which correspond to each area.

![Table 5: Compact table of summary statistics: Sum values by neighborhood in Umeå](image)

On the next graph the levels of vehicle ownership per 1.000 residents has been calculated for every neighborhood. The total number of private vehicles divided by total population for each area and finally multiplied by 1.000 residents. Figure 3 below illustrates that the level of car ownership is considerably higher for the case of Teg and Västerslätt. Ålidhem-NUS, Ersboda-Ersmark and Central City are those areas with lower levels of private vehicles. The map in the Appendix 2 illustrates vehicle ownership per 1.000 residents.

![Figure 3: 2016 Vehicle ownership per 1000 residents, by neighborhood. Source: Transport Analysis](image)
The next step is to visualize the average income and population density for each neighborhood. In this context, it is remarkable that Teg and Västerslätt appear with lower population density. This may indicate the probability of population density being connected with high automobile dependency, but this will be investigated afterwards with the use of OLS regression. As it concerns the average income it is obvious that there are no considerable variation between the regions. However, it should be noted that the regions with the lowest income are also associated with lower vehicle ownership rates (Ersboda-Ersmark and Ålidhem-NUS). The Table 6 has been formulated with the command of:

<table>
<thead>
<tr>
<th>Area_name</th>
<th>AvgInc</th>
<th>Pop_Dens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backen</td>
<td>221399.1</td>
<td>26.37374</td>
</tr>
<tr>
<td>Central City</td>
<td>226046.2</td>
<td>49.1738</td>
</tr>
<tr>
<td>Ersboda-Ersmark</td>
<td>161722.3</td>
<td>20.69515</td>
</tr>
<tr>
<td>Haga-Sandbacka-B</td>
<td>216714.9</td>
<td>34.89039</td>
</tr>
<tr>
<td>Marieområdet</td>
<td>212379.8</td>
<td>51.90671</td>
</tr>
<tr>
<td>Teg</td>
<td>225377.1</td>
<td>17.55098</td>
</tr>
<tr>
<td>Tomtebo</td>
<td>211322</td>
<td>63.4784</td>
</tr>
<tr>
<td>Västerslätt</td>
<td>219269.8</td>
<td>18.01525</td>
</tr>
<tr>
<td>Ålidhem-NUS</td>
<td>198245.9</td>
<td>35.83691</td>
</tr>
</tbody>
</table>

So, it is clear that Tomtebo area is the one with the highest density. Then follows Marieområdet and Central City. Teg and Västerlått areas are the least densely populated areas and possibly that consists one of the reasons that have high car occupancy rates. But this will be proven afterwards. The map in the Appendix 1 illustrates population density.

Furthermore, it is interesting to investigate the numbers of households with two or more vehicles. On the graph below appear these neighborhoods for the year of 2014 (Umeå Municipality, 2014a).
At this point it is important to examine and visualize travel preferences based on data aggregated from the RVU Survey. These trips refer to working trips and trips to reach services and shopping activities. According to RVU survey most respondents travel daily between Ålidhems/NUS and Central city. The next most common route is between Ersboda/Ersmark and Central city. Afterwards, it follows the route between Haga/Sandbacka/Berghem and Central city (RVU 2014, MUNICIPALITY OF UMEÅ).

Table 7. Percentage of Umeå commuters by transportation mode choice

<table>
<thead>
<tr>
<th>Region</th>
<th>Car</th>
<th>Bus</th>
<th>Bike</th>
<th>By foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haga/Sandbacka/Berghem</td>
<td>42%</td>
<td>5%</td>
<td>36%</td>
<td>15%</td>
</tr>
<tr>
<td>Ersboda/Ersmark</td>
<td>68%</td>
<td>12%</td>
<td>13%</td>
<td>6%</td>
</tr>
<tr>
<td>Marieområdet</td>
<td>60%</td>
<td>9%</td>
<td>21%</td>
<td>9%</td>
</tr>
<tr>
<td>Centrala stan</td>
<td>40%</td>
<td>9%</td>
<td>30%</td>
<td>21%</td>
</tr>
<tr>
<td>Västerslätt</td>
<td>66%</td>
<td>3%</td>
<td>25%</td>
<td>6%</td>
</tr>
<tr>
<td>Backenområdet</td>
<td>63%</td>
<td>9%</td>
<td>20%</td>
<td>7%</td>
</tr>
<tr>
<td>Ålidhem/NUS-området</td>
<td>38%</td>
<td>9%</td>
<td>39%</td>
<td>14%</td>
</tr>
<tr>
<td>Teg</td>
<td>66%</td>
<td>3%</td>
<td>20%</td>
<td>7%</td>
</tr>
<tr>
<td>Tomteboområdet</td>
<td>42%</td>
<td>14%</td>
<td>24%</td>
<td>19%</td>
</tr>
</tbody>
</table>

In general, the citizens’ primary reason for commuting is to reach their working destination. It can be seen that the neighborhood of Ålidhems/NUS is the most popular destination for employees as well as it seems that this area is marked by most school-oriented routes. Trips are made by car, bus, bike and foot respectively.

Also it seems that areas such as Ersboda/Ersmark, Teg and Västerlätt are more addicted to automobile dependency with 68%, 66% and also 66% respectively. On contrary Marieområdet, Central city and Ålidhem/NUS are these areas with lower values of car dependency. Marieområdet is the one with 6% respectively.

Tomteboområdet and Ersboda/Ersmark are these areas that prefer the use of bus in contrary to Teg area which has the lowest value with 3%. As it concerns the use of alternative transport modes there are some areas which cycle or walk more. The bicycle is used for short trips to work, shops or other activities.

Moreover it is clear that the residents of Ålidhem/NUS area andHaga/Sandbacka/Berghem appear to use their bikes more often with 39% and 36% respectively. In the case of Teg and Backenområdet the level of cycling is about 2% while in the Central city is around 3%.

Finally, walking as a means of transport is commonly used along the Central city, where the survey shows that 21% of all trips made by foot. Rates of walking vary across the city with Ersboda/Ersmark and Västerlätt to have a rate of approximately 6% whilst Teg and Backenområdet to be around 7%.
6.4. **Socioeconomics and Travel Habits**

The first correlation analyses is executed in order to examine how socioeconomic characteristics are connected to car ownership. Car ownership appear to have strong relationship with educated population, men, women and also population over 25 years old. The strongest correlation seems to be with ages between 45 to 64 years old. As also shown in Table 8 below, there is a moderate to low positive correlation between car ownership and average income, while a lower relationship to exist between car ownership and employment density.

| Table 8. Correlation Coefficients between Car Density and Socioeconomic characteristics |
|-----------------------------------------|-----------------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Car Ownership                          | Average Income                   | Educated 25-64 | Men            | Women           | Age 20-24       | Age 25-44       | Age 45-64       | Age 65+         | Employment Density |
| Car Ownership                          | 1.000                            | 0.2077         | 0.4409*        | 0.4550*         | 0.4938*         | 0.4550*         | 0.4938*         | 0.4550*         | 0.4938*         | 0.4550*         | 0.4938*         |
| Average Income                         | 0.2077                           | 1.000          | 0.0936         | 0.1158          | 0.1399          | 0.7402*         | 0.7432*         | 0.7955*         | 0.6255*         | 0.6459*         | 0.7295*         |
| Educated 25-64                         | 0.4409*                          | 0.0936         | 1.000          | 0.9924*         | 0.9791*         | 0.9497*         | 0.9427*         | 0.9427*         | 0.9427*         | 0.9427*         | 0.9427*         |
| Men                                    | 0.4550*                          | 0.1158         | 0.9924*        | 1.000           | 0.9791*         | 0.9497*         | 0.9427*         | 0.9089*         | 0.8625*         | 0.8625*         | 0.8625*         |
| Women                                  | 0.4938*                          | 0.1399         | 0.9791*        | 0.9866*         | 1.000           | 0.9497*         | 0.9427*         | 0.9089*         | 0.8625*         | 0.8625*         | 0.8625*         |
| Age 20-24                              | 0.1872                           | -0.1300        | 0.7402*        | 0.7432*         | 0.6820*         | 1.000           | 0.9497*         | 0.9427*         | 0.9427*         | 0.9427*         | 0.9427*         |
| Age 25-44                              | 0.3377*                          | -0.0177        | 0.9497*        | 0.9427*         | 0.9089*         | 0.8625*         | 1.000           | 0.9497*         | 0.9427*         | 0.9427*         | 0.9427*         |
| Age 45-64                              | 0.5217*                          | 0.3082*        | 0.7955*        | 0.8036*         | 0.8476*         | 0.2669*         | 0.5784*         | 0.6255*         | 0.6459*         | 0.7295*         | 0.2422         |
| Age 65+                                | 0.4798*                          | 0.2661*        | 0.6255*        | 0.6459*         | 0.7295*         | 0.2422         | 0.4402*         | 0.4402*         | 0.8383*         | 1.000           | 0.4402*         |
| Population Density                     | 0.1885                           | 0.0030         | 0.7112*        | 0.7139*         | 0.6969*         | 0.7164*         | 0.7692*         | 0.7692*         | 0.4081*         | 0.4081*         | 0.4081*         |
| Employment Density                     | 0.0857                           | -0.1209        | 0.6391*        | 0.6198*         | 0.5764*         | 0.7650*         | 0.7335*         | 0.2311         | 0.2307         | 1.000           | 0.2307         |

* p < 0.05

On the next step will be investigated the correlation between the number of commuters for work, shopping and services respectively, and the percentage of commuters by car, bus, bike and by foot. By this way it is easy to realize that each activity can be linked to the choice of a specific means of transport based on the preferences of the citizens.

So, as it has been proved previously, there is a strong relationship between the use of private cars and commuters for work or shopping, while there is a moderate relationship in the case of services. Additionally, the coefficients reveal that bus, bike or foot as a travel mode choice are highly related with the number of working trips. Furthermore, as it is expected there is moderate relationship between travel mode choices and commuting for shopping or services.
Table 9. Correlation Coefficients between Mode Choice Variables and Reasons of Commuting

<table>
<thead>
<tr>
<th></th>
<th>Number of commuters for Work</th>
<th>Number of commuters for Shopping</th>
<th>Number of commuters for Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Travel by Car</td>
<td>0.8377*</td>
<td>0.8631*</td>
<td>0.6984*</td>
</tr>
<tr>
<td>% Travel by Bus</td>
<td>0.7207*</td>
<td>0.6880*</td>
<td>0.5725*</td>
</tr>
<tr>
<td>% Travel by Bus</td>
<td>0.8498*</td>
<td>0.5230*</td>
<td>0.5678*</td>
</tr>
<tr>
<td>% Travel by Foot</td>
<td>0.7468*</td>
<td>0.3881*</td>
<td>0.5358*</td>
</tr>
</tbody>
</table>

The next step was to investigate how travel behavior variables are connected with urban form. For that reason the next table has been created. As can be seen, there is a strong linear relationship between population density and especially the use of bike for commuting. Evidently, the overall conclusion is that employment density as well as population density appear to have a moderate relationship with any kind of travel mode choice. On contrary, there is no evidence that there is correlation with the Entropy Index.

Table 10. Correlation Coefficients between Mode Choice Variables and Urban Form variables

<table>
<thead>
<tr>
<th></th>
<th>Employment Density</th>
<th>Population Density</th>
<th>Entropy</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Travel by Car</td>
<td>0.4426*</td>
<td>0.5841*</td>
<td>-0.0532</td>
</tr>
<tr>
<td>% Travel by Bus</td>
<td>0.5377*</td>
<td>0.6496*</td>
<td>-0.1109</td>
</tr>
<tr>
<td>% Travel by Bus</td>
<td>0.6799*</td>
<td>0.7425*</td>
<td>0.1074</td>
</tr>
<tr>
<td>% Travel by Foot</td>
<td>0.5772*</td>
<td>0.6798*</td>
<td>0.1239</td>
</tr>
</tbody>
</table>

These findings reveal that there is an estimation about how a part of residents tend to use private vehicles, in order to reach their work destination or for shopping activities. Still, by the same way there is a big part of the city that commuting to work by bus, bike or foot, despite the fact that the use of these alternative modes is less frequent for shopping or services. Finally, it has been proved that employment and population densities consist indicators that are directly connected with travel behavior.
6.5. **ILLUSTRATION OF POPULATION DENSITY AND ENTROPY**

It is also reasonable to investigate how formulates the relationship between vehicle ownership and population density as well as between vehicle ownership and entropy respectively. The next figure depicts in details the relationship between private cars per 1,000 residents and population density for each neighborhood within the city.

![Scatterplot with overlaid linear prediction plot Private Cars (per 1,000 residents) vs. Population Density by neighborhood](image)

All the presented results are a visualization to a deeper understanding of the relationships between vehicle ownership and densities that are shaped in each area. For instance, low levels of population density in the Backen, Teg and Västerlått regions seem to favor the possession of more vehicles. In contrast, Marieområdet and Ålidhem-NUS are those regions where there is a slight decrease of private vehicles as population density increases. On the other hand, the Central City seems to have quite increased levels of private cars despite its densely populated area.

Correspondingly, the figure below illustrates the relationship between private vehicles per 1,000 residents and the Entropy Index for each neighborhood inside the city of Umeå.

It seems that the regions such as Haga-Sandbacka, Teg and Central city tend to keep their values of vehicle ownership at high levels, despite the fact that in these areas there is mixed land use. Ersboda-Ersmark, Västerlätt and Ålidhem-NUS are these regions with mixed land use within as well as with lower vehicle ownership.
On that point, it should be noted that there is no region which is described as totally heterogeneous. So, this may be a possible reason why vehicle ownership rates remain high in the small town of Umeå.

### 6.6. Regression Models

In order to be considered further the relationship between vehicle ownership and urban form this study continues with the use of regression analysis. All those factors influence automobile dependency will be investigated. Furthermore, there any contribution of mixed land use (residential, commercial, industrial) and population density in the way residents choose to move will be considered.

Two hypothetical scenarios are used in an experiment to define the relationship between the dependent and independent variables.

**Hypothesis**

**H1:** Low population densities in urban and suburban areas tend to increase the levels of vehicle ownership.

**H2:** Mixed-use environments contributes to less car dependence. Conversely, mixed-use development (residential, commercial, and industrial) tend to increase sustainable transit and walking.

The statistical significance level for testing the null hypotheses is 5% (0.05).
6.6.1. Regression model of Vehicle Ownership

The first set of analyses investigates how low population densities in urban and suburban areas may cause an increase in vehicle ownership.

So, the Table 11 below presents the regression results for predicting variation in the dependent variable of vehicle ownership.

Table 11. OLS Regression results on factors influencing vehicle ownership inside SAMS areas

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>POPULATION DENSITY</td>
<td>7.392967</td>
<td>3.254099</td>
<td>2.27</td>
<td>0.027</td>
</tr>
<tr>
<td>SINGLE TENANTS</td>
<td>1.52967</td>
<td>0.3993997</td>
<td>3.83</td>
<td>0.000</td>
</tr>
<tr>
<td>COMMERCIAL AREA (HA)</td>
<td>37.22686</td>
<td>17.31959</td>
<td>2.15</td>
<td>0.036</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-66.07558</td>
<td>172.6223</td>
<td>-0.38</td>
<td>0.703</td>
</tr>
</tbody>
</table>

Number of observations: 59  
R-Squared: 0.25

In this model as dependent variable defined vehicle ownership while as independent variables defined population density, single tenants and the presence of commercial area within neighborhood expressed in hectares respectively. The regression model indicates that the level of vehicle ownership tend to increase with any increase of population density, singe tenants and commercial area.

The model describes around 25% of the total variability of the response data around its mean. Obviously, from the previous model occurs that the automobile dependency were found to be significantly related to commercial areas, but also there is a positive relationship between vehicle ownership and population density. Based on that the first hypothesis that low population densities lead to high levels of automobile dependency cannot be proved.
6.6.2. Regression model of Auto

The second regression model examines the contribution of the build environment on percentage of commuters by car. The dependent variable AUTO describes the percentage of commuters by car.

Table 12. OLS Regression results on factors influencing the use of private vehicle inside SAMS areas

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>POPULATION DENSITY</td>
<td>10.37471</td>
<td>2.838091</td>
<td>3.66</td>
<td>0.001</td>
</tr>
<tr>
<td>COMMERCIAL AREA (HA)</td>
<td>-6.267639</td>
<td>2.400415</td>
<td>-2.61</td>
<td>0.012</td>
</tr>
<tr>
<td>INDUSTRIAL AREA (HA)</td>
<td>-7.410498</td>
<td>3.141092</td>
<td>-2.36</td>
<td>0.022</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>619.4151</td>
<td>132.145</td>
<td>4.69</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Number of observations: 59
R-Squared: 0.46

AUTO variable has been constructed by taking the percentage of commuters by car from RVU 2014 survey and adjusted with the total population of each SAMS area. As independent variables defined population density, commercial and residential area both expressed in hectare.

The previous regression model describes around 46% of the total variability of the response data around its mean. The model suggests that the levels of commuting by car are rising as population density rises. Moreover as commercial or industrial area decline, commuters by car tend to rise. So in this case the second hypothesis that mixed-use environments lead to less car dependence can be confirmed.

6.6.3. Regression model of Bus

The next set of analyses is concentrated on how land-use characteristics affect the use of bus as travel mode choice. The regression model describes around 56% of the total variability of the response data around its mean. It examines all those variables that affect the variable of BUS which describes percentage of commuters by bus. This variable has been constructed by taking the percentage of commuters by bus from RVU 2014 survey and adjusted by the total population in every SAMS area.
A regression analysis was performed in order to investigate the effects of the overall build environment on bus trip rates. Population density, single tenants and the presence of commercial area within neighborhood may force the use of bus for commuting. So the second hypothesis that mixed-use environments tend to increase the use of sustainable transportation can be confirmed.

### 6.6.4. Regression model of Bike

The next regression model describes around 72% of the total variability of the response data around its mean. This model is investigating how land-use characteristics affect the use of bike as travel mode choice. BIKE variable describes the percentage of commuters by bike. It has been constructed by taking the proportion of commuters by bike from RVU 2014 survey and adjusted by the total population in every SAMS area.
the model reveals that high population densities but also any rise of commercial or residential area force the rise of commuting by bike. By this way the second hypothesis that mixed-use environments tend to increase the use of sustainable transportation can be confirmed.

6.6.5. Regression model of Walking

The next regression model describes around 65% of the total variability of the response data around its mean. This model is investigating how land-use characteristics walking choice within neighborhoods. WALKING variable describes the percentage of residents commute on foot. It has been constructed by taking this proportion of commuters from RVU 2014 survey and adjusted by the total population in every SAMS area.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>POPULATION DENSITY</td>
<td>5.299416</td>
<td>.6347176</td>
<td>8.35</td>
<td>0.000</td>
</tr>
<tr>
<td>COMMERSE AREA (HA)</td>
<td>1.603347</td>
<td>.3533043</td>
<td>4.54</td>
<td>0.000</td>
</tr>
<tr>
<td>RESIDENTIAL AREA (HA)</td>
<td>.2654512</td>
<td>.071557</td>
<td>3.71</td>
<td>0.000</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-115.2808</td>
<td>32.24833</td>
<td>-3.57</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Number of observations: 59
R-Squared: 0.65

This regression model suggests that population density has a positive relationship with the rates of commuters by walking. By the same way, a positive relationship appear with the independent variable of commerce and residential area. As it is obvious the model indicates that high population densities but also any rise of commercial or residential area force the rise of commuting by walking. By this way the second hypothesis that mixed-use environments tend to increase the use of sustainable transportation and walking can be confirmed.
7 CONCLUSION

This research focused on the way land use have impact on human travel habits. It is important to perceive how land uses are classified in space to ensure functionality and resilience. By this way it is possible to have a better understanding within space with final goal to improve the effectiveness of urban planning. It is a step to a better operation of sustainable transport development and a cause to rethink prospects for improvement or challenges exist.

With the use of the Entropy index, it has been proved that there is no complete heterogeneity in land uses within the neighborhoods of Umeå. For this reason the entropy measure will be excluded as an independent variable from the regression models due to the fact that it had been recognized as non-significant factor.

Vasanen (2013) refers that high density and mixed land use appear to contribute to lower levels of vehicle ownership. In this study, on contrary to this theory the levels of vehicle ownership were found to be increased with any presence of commercial areas and high population density. As we go further with this study there is an additional contradiction in relation to what Litman (2017) argued previously on the theoretical part. It has been referred that lower population densities within neighborhoods are linked to high automobile dependency (Litman, 2017). From this study occurs that the levels of commuting by car within the neighborhoods of Umeå are rising as population density rises. Furthermore the presence of commercial or industrial areas within neighborhoods eliminate commuters by car. But in this case the second hypothesis that mixed-use environments lead to less car dependence can be confirmed.

Additionally, it has been revealed that factors such as population density, single tenants and the presence of commercial area within neighborhood may force also the use of bus for commuting. Yamada et.al (2012) argues that population density and land use diversity consist factors that define travel patterns. These arguments can be confirmed through this study as bus commuting seems to be affected positively by high densities and mixed land use. Especially commercial areas appear to force commuting by bus.

Reynolds et.al. (2009) refers also how the built environment consist an important determinant of bicycling rate. As the second hypothesis also confirmed in the present research it is clear that high population densities but also any rise of commercial or residential area force the rise of commuting by bike.

Another important fact that this study indicates is that the presence of commercial areas in combination with residential areas are capable to rise walking. This confirm Brown et. al. (2009) arguments that mixed land use seems to encourage residents to walk to the wider area of their residence.
Furthermore, what can also be drawn from the models is the final conclusion that mixed-use environments tend to increase the use of sustainable transportation and walking. It is possible to conclude that any implementation that aims to separate land uses are capable to cause high levels of automobile dependency and to prevent sustainable development in transportation (French, 2012). Health problems caused by low physical activity associated also with obesity and pollutant emissions by vehicles are some briefly described problems that might arise (Booth et.al.; Brown et al., 2009, p.1130).

It should be noted that automobile dependency is fully connected to shopping or working activities. As it has been observed the presence of commercial or industrial areas within the neighborhoods reduce private vehicle use, while at the same time force the use of alternative, sustainable transport modes. Teg and Västerlått are these neighborhoods where the use of private vehicles is more frequent than any other transport mode option. On contrary, Ålidhem seems to support more sustainable transportation choices.

At this point, it should be mentioned how ideal it is to ensure homogeneity and equality in order to eliminate any observable functional inequalities between areas that constitute a city. From the research that has been performed, it is possible to conclude that travel behavior can probably defined by land use factors. Population density appear as a dynamic component that have impact on sustainable transportation choices. As it has been observed, population density enhance the use of sustainable transport modes such as bus, cycling and walking.

The findings concerning mixed land use was quite surprising when the Entropy index reveals low levels of mixed land use within the city. Nevertheless, it seems that any presence of commercial or industrial land use within residential areas contribute to reducing automobile dependency and support sustainability. Finally, it should be noted that this research is mainly focused on the horizontal land cover without taking into consideration the vertical use of each floor in every building. This would be an interesting in-depth research as a continuation of this study.

### 7.1 Future studies

Future research should examine strategically the use of intelligent technologies in order to organize the urban landscape in a more efficient way. The role of big data is important for shaping smart environments that responds to the citizen’s needs and ensuring a more functional lifestyle as well as a more secure environmental development. Proper and prudent management of the huge amounts of data captured in cities, seems to be capable of improving the services and internal networks of cities. Problems cause constantly difficulties within the urban space as the population grows. This fact creates an overflow of activities as well as the use of private vehicles that need to be controlled. The ever-increasing traffic
congestion and the corresponding loss of time are also serious factors in terms of security and quality of life. Undeniably, something more than just land use factors need to be integrated in planning strategies for the cities of tomorrow.

As Roche (2016) highlights it is necessary to perceive the concept of the city as a network of interconnected points rather than as a set of points sorted in the space. Moreover, the meaning of smart describes the city’s ability to perceive events through sensors and the use of ICT (Roche, 2016, p.571). It is commonly accepted that the rapid growth rate of cities requires more efficient analysis techniques to deal with big data for the right decision-making. Land uses change rapidly within urban environment, while more and more uses are mixed together to meet the needs of ever-growing cities. Researches refers to «dynamic urban land use patterns» where citizens have the ability to interact directly with their surroundings through their personal smart devices (Wang et.al., 2016, p.1)

Additionally, it is a fact that rapid population growth leads to high population density and as a result, the density of smart devices in the urban landscape follows an upward trend too. Embedded devices such as «smart home sensors, vehicular networking, weather and water sensors, smart parking sensors, and surveillance objects» are part of the urban fabric that now create new possibilities in decision-making (Rathore et. al., 2016, p.63). Thus, it is obvious that more and more users participate in the decision-making process, as their preferences in everyday life are captured in space as they move around.

Consequently, the final stage of the planning process can be carried out more accurately and efficiently, since the data obtained are continually updated. Urban and planning research now is more focused on smart digital technologies that provide results with greater accuracy. It is also, important to note the limitations of conventional research methods, which were based on random samples at random times, while nowadays systems are designed to continually monitor and update information. Real-time web gives researchers the opportunity to engage in a wider range of data and to work more effectively against the problems of analyzing cities. Furthermore, the research process tend to be easier, faster and at a lower cost (Silva, 2012, p.1-2). Finally, the use of smart applications make visualization of the results to be straightforward while at the same time simplify the mixing of qualitative and quantitative methods (Lobe & Vehovar ; Silva, 2012, p.2).

Smart cities should learn how to deal efficiently with big data to favor health, transportation, energy, education, and water services and to ensure high quality of life (Al Nuaimi et.al., 2015,p.1). Undoubtedly, big data actually help cities address the problems they face but, alongside opportunities, dilemmas also emerge. It is therefore essential, all these data to be used in such way that it does not harm the human being. It is vital to remember that the main recipient of any development is the human factor.

Admittedly, it is important to identify that population and social change, as well as technological evolution have significant impact on the urban landscape which is obviously directly linked to human factors. Research refers that «land use and land cover change
(LUCC), a prominent feature in the field of global change is the direct effect on the natural environment provoked by human activities». In conclusion, the ultimate goal is to ensure healthy, attractive and vibrant cities for future generations. Thus, strategic planning it is essential to utilize big data in such a way that it is possible to success balance distribution of land uses and to create a sophisticated urban landscape.
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