TÉCNICO LISBOA

Mobility vs. Sustainability

Car Sharing as a Key Concept for Sustainable Mobility in Greater Lisbon

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Abstract

Individual mobility – not only expression of human needs, but also a prerequisite for the functional and economic capability of today's modern society. Spatial mobility and, subsequently, the choice of transportation mode, is of central significance in this regard. The passenger transport in many European cities, such as in Greater Lisbon, is nowadays still characterized by a predominance of automobiles, not only for reasons of constant availability and high flexibility. Cars are still an expression of status and prosperity, particularly in Southern European countries, as the evolution of the number of passenger cars in the European Union reveals. However, attached to individual car ownership are numerous negative ecological, economic and social side effects, such as noise pollution, land use, traffic accidents, cost of traffic congestions and not least the emissions of harmful greenhouse gases. To counteract the negative consequences of increasing road traffic, sustainable mobility concepts, closely linked to sustainable development, have to further shift into the focus of public interest prospectively. Property-less car usage, so-called "car sharing", is seen by many authors to offer a highly promising approach to reduce these negative effects of transport mentioned, while preserving the individual mobility. Nonetheless, car sharing concepts are nowadays still far away from reaching widespread use in many European regions, like in Greater Lisbon as well. In order to depict a positive contribution for an increasingly sustainable, innovative and competitive environment in Greater Lisbon, car sharing is investigated from the point of view of sustainable development within the scope of the present dissertation. The results demonstrate that an innovative and locally adapted car sharing concept may help to counteract the ecologically and economically unfavorable trend of increasing traffic volume in Greater Lisbon, while highlighting that social acceptance of shared car use is necessary, but alone not sufficient to push such a mobility concept towards a wider spread.

Keywords: Car sharing; Sustainable Development; Greater Lisbon; Mobility; Traffic

Resumo

Mobilidade individual – não só é uma expressão das necessidades humanas, como também um prérequisito para a capacidade econômica e funcional da sociedade moderna atual. Mobilidade espacial e, posteriormente, a escolha do modo de transporte, é de importância central neste aspecto. Em muitas cidades europeias, como a Grande Lisboa, o transporte de passageiros é ainda hoje caracterizado pela predominância de automóveis, não só por razões como a disponibilidade constante e a alta flexibilidade. Carros ainda são considerados como uma expressão de status e prosperidade, particularmente nos países do sul da Europa, como é mostrado pelo aumento do número de automóveis de passageiros na União Europeia. No entanto, associado à posse de carros individuais estão os inúmeros efeitos ecológicos, econômicos e sociais negativos, como poluição sonora, uso da terra, acidentes de trânsito, custos dos congestionamentos e ainda emissões de gases de efeito estufa nocivos. Para combater as consequências negativas do aumento de trânsito, conceitos de mobilidades sustentáveis, estreitamente associados ao desenvolvimento sustentável, precisam focar cada vez mais no interesse público. A desaposse de carros privados, o chamado “car sharing”, é visto por muitos autores como uma abordagem altamente promissora no que diz respeito à redução dos efeitos negativos mencionados, enquanto que preservando a mobilidade individual. Entretanto, os conceitos de *car sharing* atuais, estão ainda longe de alcançar o uso generalizado em muitas cidades europeias, incluindo a Grande Lisboa. A fim de retratar uma contribuição positiva na Grande Lisboa para um ambiente mais sustentável, inovador e competitivo, *car sharing* é investigado do ponto de vista do desenvolvimento sustentável no âmbito do projeto de pesquisa. Os resultados demonstram que um conceito de *car sharing* inovador e localmente adaptado poderia ajudar a combater as tendências ecológicas e econômicas desfavoráveis do aumento do volume de tráfego na Grande Lisboa. Ademais, é importante destacar que a aceitação social do uso de carros compartilhados é necessária, mas não suficiente para impulsionar esse conceito de mobilidade em direção a uma disseminação mais ampla.

Palavras-chave: Car sharing; Desenvolvimento Sustentável; Grande Lisboa; Mobilidade; Tráfego

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1 Introduction

1.1 Motivation

According to McGlade (2012), former executive director of the European Environment Agency (EEA), "one of the big challenges of the 21st century will be to mitigate the negative effects of transport – greenhouse gases, air pollution and noise – while ensuring positive aspects of mobility". A growing world population and increasing prosperity in conjunction with the tendency towards urbanization have led to an excessive number of vehicles in cities and metropolitan areas all around the globe. Although the population in Europe is declining slightly, rising demands for mobility caused by various factors, such as demographic changes, are generating immense volumes of traffic in urban areas (Akkoc 2015). Other phenomena, such as the silhouettes of old cities with their jumble of narrow streets that are often found in Southern Europe, intensify the problems with road congestion and a lack of parking spaces.

However, mobility is not only an expression of human needs but also a prerequisite for the functionality and economic performance of today's society. Nowadays, businesses require a high degree of geographical mobility, which is closely linked to the choice of transport mode. Passenger transport in European cities is still characterized by a predominance of automobiles for reasons of constant availability and high flexibility (EEA 2014c). What from a user's perspective seems to be the most convenient transportation method is accompanied by numerous negative environmental, economic, and social side effects. Noise pollution, land use, traffic accidents, air pollutant emissions, and not least the emissions of harmful greenhouse gases are just some problems that largely result from car traffic and are contrary to the requirements of sustainable development. Hence, the two terms "mobility" and "sustainability" are today opposed and do not complement each other – in other words mobility vs. sustainability. Nevertheless, sustainable mobility concepts, which are further and further shifting into the center of public interest could bring mobility and sustainability back into harmony. Especially property-less car use, or so-called "car sharing", could offer a highly promising approach to reduce the negative environmental consequences while preserving individual mobility.

Nonetheless, there is still a number of question marks hanging over this concept: are car sharing offerings able to acquire new user groups? What is the viability of car sharing in a sustainability context? How can social acceptance of shared use be created and maintained?

1.2 Research Question

The main purpose of the present dissertation is to answer the following research question: could car sharing offer a sustainable mobility solution for Greater Lisbon?

1.3 Objective

In particular, the objective of the dissertation is to determine whether a use-oriented product-service system, namely car sharing, could offer a more sustainable mobility solution than private vehicles for metropolitan areas in Europe and, in this way, also generate positive environmental, social, and economic effects.

This dissertation will focus on Portugal, in particular on the subregion Greater Lisbon, where car sharing concept is developed and investigated regarding its potential to reduce traffic related problems. Special emphasis is placed on the municipality of Lisbon, since it presents the greatest municipality with the highest traffic in the region of Greater Lisbon and best available information.

1.4 Structure

The dissertation includes nine chapters; a schematic overview of the structure is illustrated in Figure 1 below.

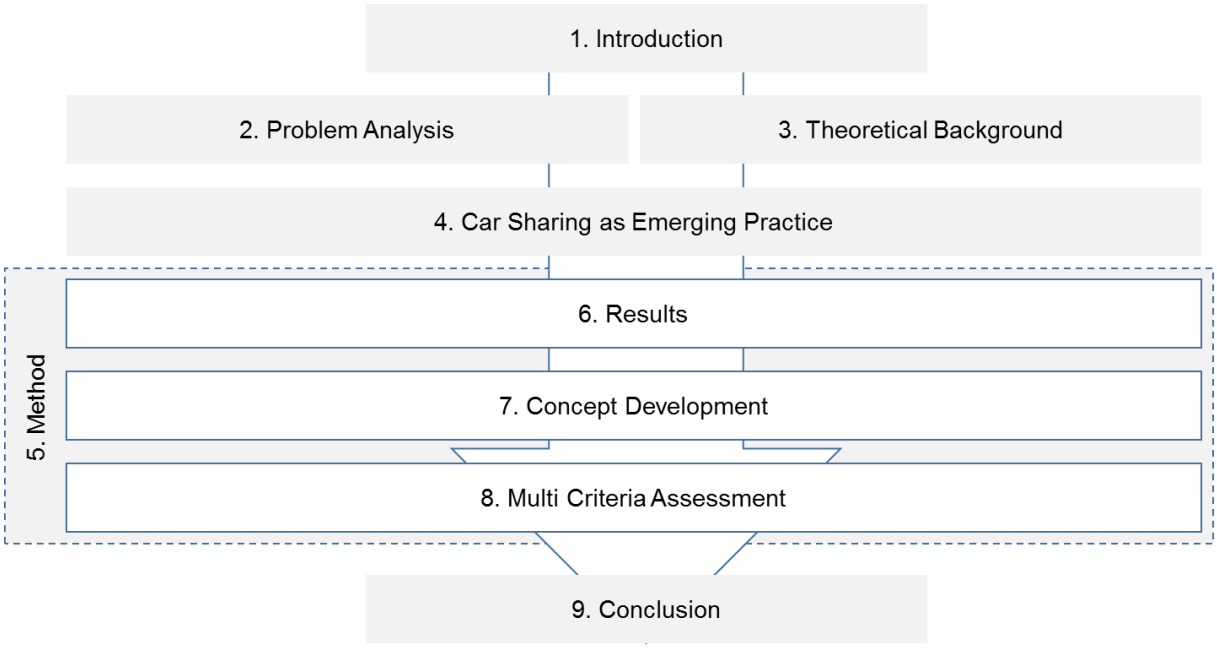

Figure 1. Schematic overview of the dissertation (Own graph)

The first part of the dissertation (the introduction) explains the motivation for the study and goes immediately to the contextualization of the problems of increasing road traffic in Europe in the second chapter.

The problem analysis section that follows provides the foundation for achieving the major goal: in order to be able to answer the research question – could car sharing offer a sustainable mobility solution for

Greater Lisbon – it is first necessary to analyze the transportation related problems by identifying the causes and effects of the current traffic evolution in the Portuguese subregion.

The theoretical foundations of sustainability and sustainable development, which form the background for the understanding of the following discussions, are then introduced, and the so-called “product-service system” based on mobility is explored in terms of its environmental and sustainability benefits.

Subsequently, the economic, environmental, and social dimensions that make car sharing a sustainable mobility concept are analyzed theoretically based on an in-depth literature and web review. Afterwards, the dissemination of car sharing in Europe is investigated, which allows one to draw first conclusions on the cultural differences and the varying acceptance levels of car sharing schemes in the European Union (EU). The study then focuses on international experiences with car sharing in countries with cultures comparable to that of Portugal, and the contribution of car sharing to sustainable development is investigated.

Furthermore, the research methods that have been applied in the preparation of the dissertation are demonstrated, and the corresponding results are then illustrated and analyzed. In accordance with the insights and findings thus gained, a locally adapted car sharing service will be proposed and assessed according to sustainability afterwards. Thereby, the research question can sufficiently be answered in the last chapter and the dissertation ends with concluding remarks, recommendations, and a short outlook on future mobility.

2 Problem Analysis

2.1 The European Context

Transport has played an important role throughout human evolution and it is one of the main undisputed drivers of economic growth. Today more than ever, individuals and companies are taking advantage of the widespread mobility solutions available on the market, which has led to a continuous increase in the volume and complexity of transport. However, transport is not yet sustainable within the EU, and road traffic, which consists of freight and passenger transport, plays a predominant role in the European modal split. This is reflected by the large degree of energy consumption per unit of gross domestic product that goes toward road transportation (82.6% in 2013 (Eurostat 2015b)

As Figure 2 shows, the increasing need for transport solutions is still mainly satisfied by passenger cars (72%) within the EU, despite improvements in public transport (De La Fuente Layos and Luis Antonio 2007).

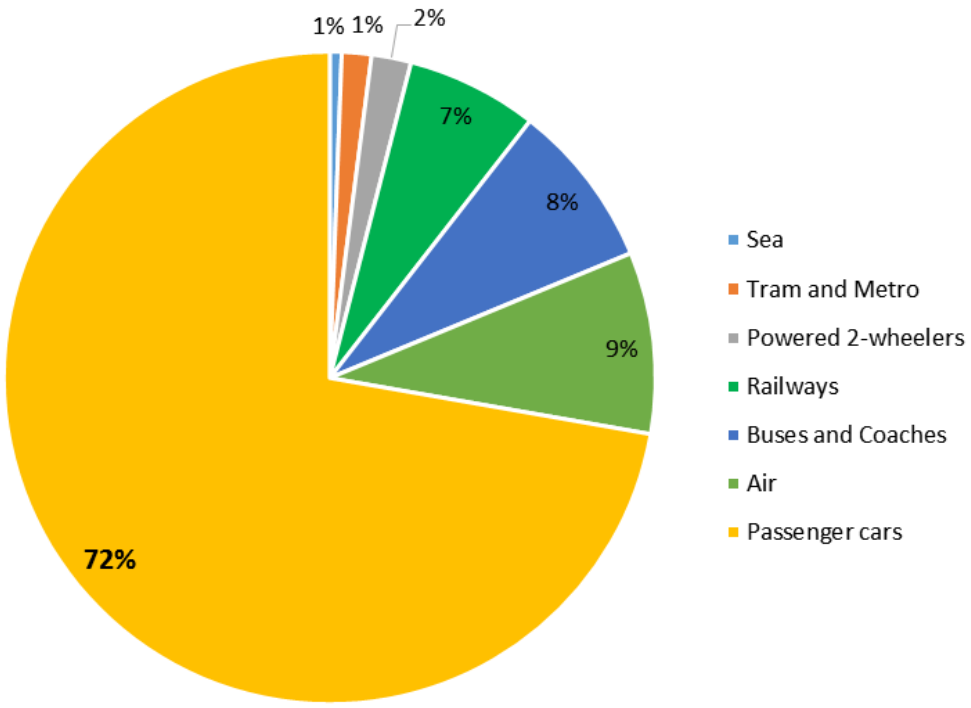

Figure 2. Passenger transport modal split within the EU-28 in 2012 (EEA 2014c)

Already in 2006, 26 of the 34 average daily kilometers travelled by each inhabitant were driven by passenger cars, and in 2009 the number of cars was half the number of all inhabitants in the EU (see also Figure 3). Seven years later, in 2013, 83.2 percent of passenger journeys were undertaken by car (Eurostat 2015b).

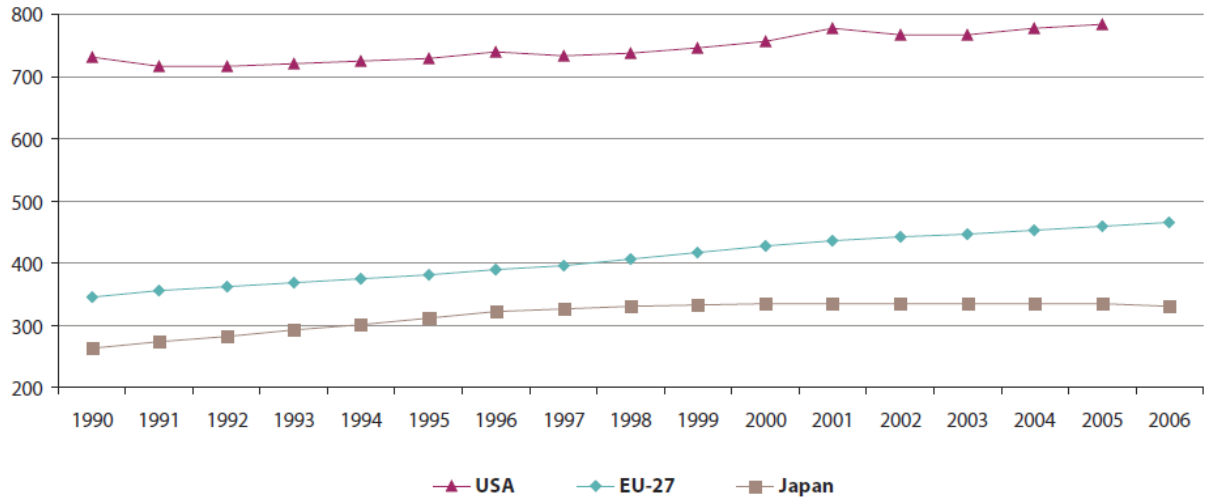

Figure 3. Number of passenger cars per 1,000 inhabitants (Eurostat 2009)

In the period from 1990 to 2006, the number of car registrations in the EU grew at an average annual rate of 2.4 percent, which can be seen as one of the main causes of the increasing traffic volume in European cities (Eurostat 2009).

Other factors have also triggered the excessive increase in the number of vehicles in cities and metropolitan areas, which will be investigated hereafter using the example of Portugal and the Greater Lisbon subregion. Furthermore, the resulting environmental effects will be analyzed and described subsequently.

2.2 The Increasing Traffic Volume in Greater Lisbon

Portugal is a coastal nation situated in Southwestern Europe with a total area of 92,090 km^2. Approximately 10,460,000 inhabitants have resided in this country in 2013 and the population density is up to 115 inhabitants per km^2, with significant agglomerations in the metropolitan areas of Lisbon and Porto. The population of Greater Lisbon – including the municipalities of Lisbon, Amadora, Cascais, Loures, Mafra, Odivelas, Oeiras, Sintra, and Vila Franca de Xira – has slightly enlarged from 1,947,261 in 2001 to 2,042,326 in 2011, and comprises about 20 percent of Portugal's entire population (AMTL 2012).

Especially the municipality of Lisbon is daily facing an immense volume of road traffic, which rose by 60 percent from 1991 to 2001 (Emel 2005). Already in 2008, 40 percent of Portugal's energy demand was triggered by the transportation sector, and road transport consumed 81 percent of this share (Baptista et al. 2012). The problem of the increasing traffic volume in Greater Lisbon results from several different causes, which are investigated in the following section (see also Annex 1).

2.2.1 Causes of the Problem

Urbanization

According to Weber and Hall (2001), urbanization can be expressed as “the fraction of individuals residing in urban areas”. The urbanization trend, which is globally rising, will lead to a world population that mainly lives in cities – up to 75 percent by 2050 according to latest yield forecasts (The Rockefeller Foundation 2015). In 2014, Europe was already one of the most urbanized continents, with 75 percent of its total population living in urban areas. This leads to some environmental advantages on one hand; for example, land use as well as energy consumption tend to be lower in more compacted cities, such as those found in Europe, than in extended lower density urban areas or rural communities. But on the other hand, urbanization significantly increases the road traffic volume in urban agglomerations. Hence, environmental problems are the inevitable consequence (Weber and Hall 2001).

In 2014 the degree of urbanization in Portugal was with 60 percent slightly under the European average, but significantly above the global trend. The main reason for the demographic shift towards urban areas in Portugal is the still present structural and economic weakness of many rural areas, and the high concentration of businesses around the two biggest cities, Porto and Lisbon (Anciaes 2015). For these reasons, the metropolitan area of Lisbon (AML) represents the highest population agglomeration in Portugal, with 2,042,326 inhabitants in 2011, in which Amadora and Odivelas constitute the cities with the highest population density in Greater Lisbon (see also Figure 4 [AMTL 2012]).

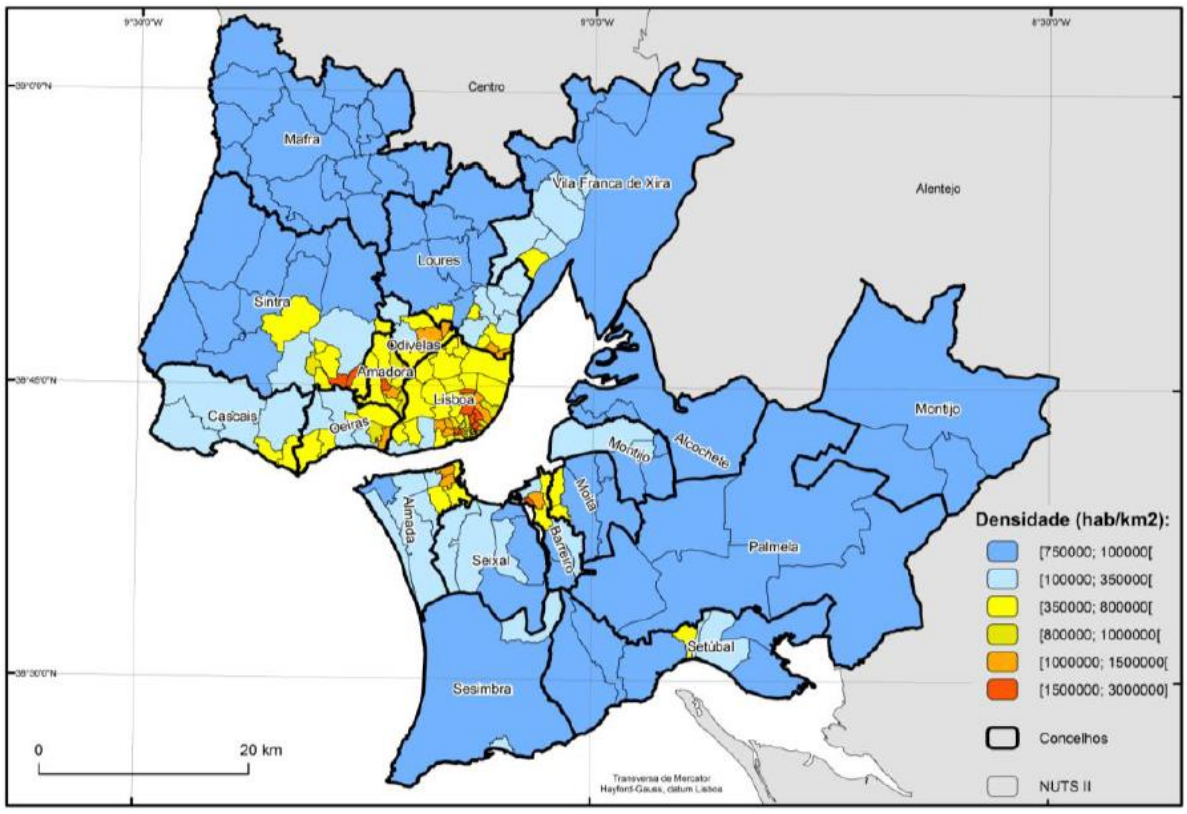

Figure 4. Population density in AML, 2011 (AMTL 2012)

Urbanization, in conjunction with other causes elucidated hereafter, has led to an increase in the road traffic in Greater Lisbon. A particularly high growth rate was recorded in Lisbon, from 210,000 vehicles per day in 1991 to 342,000 in 2001 (Emel 2005).

Public transport system

Greater Lisbon's public transport system is comprised by subway, buses, and trams, whereby buses cover the widest geographical area, and are therefore the most often chosen public transport mode with 57 percent (AMTL 2014). This results on one hand from the restricted subway network, which is rather small compared to other European capitals and metropolises – it comprises only four separated lines and a relatively low geographical coverage.

On the other hand, investments in the tram network were neglected in the last years according to *BUND*[1] (2014), despite the high touristic potential and usage level. The past underinvestment in the public transport system leads to several problems. For instance, one of the main touristic hotspots in Greater Lisbon, Belém, is only connected by one tram line and several buses, which leads to regular overloads and unpunctuality in high season. Furthermore, the expansion of area occupied in AML (compare Figure 4) leads to households located outside of the operating range of the public transport system (Emel 2005). Major consequence of this evolution is that people choose other means of transport. According to studies, cars are by far the most often chosen alternative with 77 percent (own and company cars) for those inhabitants who do not use public transport in the metropolitan area of Lisbon (compare Figure 5).

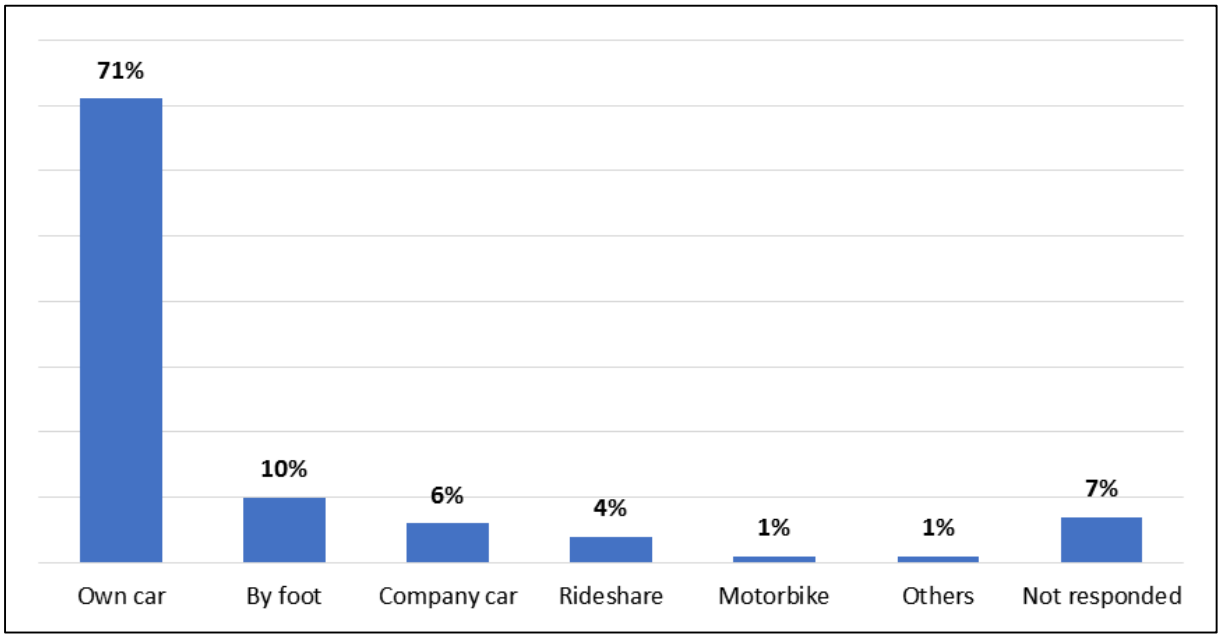

Figure 5. Chosen transportation alternatives in AML (AMTL 2014)

[1] *Bund für Umwelt und Naturschutz e.V.*: non-governmental environmental protection organization founded in 1975 in Germany.

This circumstance does not only mean, however, a burden on traffic in the city center, but also a financial burden on motorists, since vehicle-based variable costs (e.g. fuel or wear) increase, due to the higher utilization rate.

Car ownership trends

As recognizable in Figure 6, there has been a strong surge in the number of passenger cars in Portugal from 1990 to 2006. Whereas the car registrations in 1990 accounted 1,700,000 the value sharply climbed up to 4,290,000 in 2006 (Eurostat 2009). After a breakdown in 2009, the sales of light vehicle for passengers increased by 38.8 percent in 2010 (INE 2011), which reflects the still present cultural importance and needs for individual mobility in Portugal. Since the majority of Portuguese people live in urban areas, the inner-city vehicle density performed in a similar way.

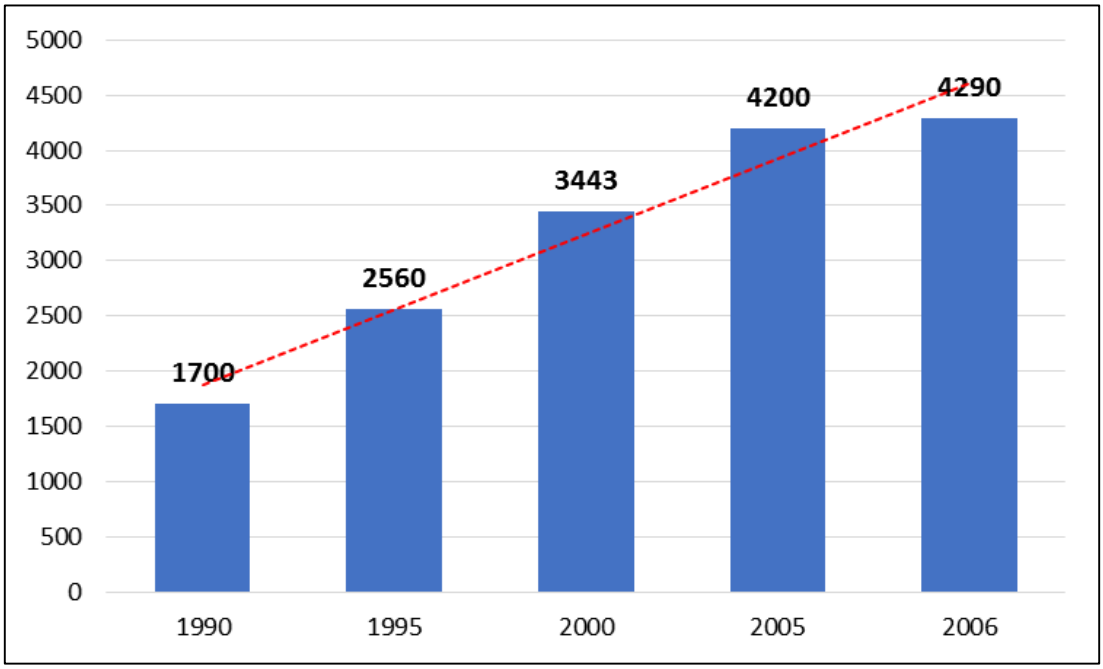

Figure 6. Number of passenger cars in Portugal (in 1000 [Eurostat 2009])

Proportion of short and single-person travels

“The Portuguese and Spanish people are the least mobile ones” in Europe, according to Weckstrom-Eno (1999), with predominantly short-distance travels high above the European average. Short-distance trips occur mainly in metropolitan areas due to the concentration of employment and education, and include daily trips to work, universities or schools. In this context the motorized private transport is by far the most often chosen transport mode in Portugal (60.36%), with 10.13 billion passenger-kilometers per year (De La Fuente Layos and Luis Antonio 2007).

As recognizable in everyday life, single person trips, especially in rush hours, represent the largest proportion of the total road traffic in Greater Lisbon.

Increasing tourism

The year 2013 was a record year for tourism in Portugal with more than 14 million people visiting the European country, 4.2 percent more than in 2012. Tourists were more than ever attracted by the mild climate, low prices, and museums within the European country (Long 2014). In this context, the municipality of Lisbon remains the most frequently visited region in Portugal, reflected by the significant growth in overnight stays of 27 percent from 2009 to 2013 (Roland Berger 2014).

It is obvious that the increasing tourism in the Greater Lisbon subregion intensified the problems with road traffic, since it triggered a high demand for mobility solutions, especially in the city center of Lisbon. The following section concentrates on the resulting effects.

2.2.2 Local Effects of the Problem

Landscape, road network and parking difficulties

One negative effect of the increasing road traffic is the landscape fragmentation, which can be defined as a rupture of established ecological connections in spatially separated areas of landscape (Planco Consulting GmbH 2007). Biologists and environmentalists identified the fragmentation of landscape and water systems as a significant cause of the decline of animal and plant species, which leads to a major threat to biodiversity. Over the last 50 years, the landscape in Europe has been more and more fragmented by the increasingly dense transport network across the continent (EEA 2011). Despite landscape fragmentation, land is getting scarce and expensive in urban areas, which is especially problematic in cities with “old” structure and hilly landscape, like in the municipality of Lisbon.

The national road network in Portugal increased by approximately 0.4 percent per year in the period from 2006 to 2010. The motorway network has expanded at a faster pace of 1.8 percent per year in the same period (INE 2011), which not only reflects rising interventions with nature, but also high construction costs. The landscape fragmentation in Portugal is most pronounced in coastal areas and the municipality of Lisbon represents the highest fragmented region within national boundaries (EEA 2011).

Noise pollution

According to city dwellers, the major source of traffic noise within Europe’s largest cities (over 250,000 inhabitants) is road traffic, as one can see from Figure 7 (EEA 2014b). This is as well an essential concern of the people residing in the municipality of Lisbon, as *Quercus*[2] revealed in 2013. The Portuguese environmental protection organization carried out noise measurements, as well as a survey about noise disturbance and health impacts in Lisbon, which has shown that “people living or studying / working in the municipality of Lisbon are the ones who complained most about road traffic noise”,

[2] *Associação Nacional de Conservação da Natureza*: Non-governmental organization founded in 1985 in Portugal (Braga), which is operating in the field of environmental protection.

whereby 38 percent of the interviewees indicated that they are affected by noise in an intermediate grade. The interviewed residents often suffered from stress, anxiety and headaches, triggered by the unreasonably high level of noise in inner-city areas (Sousa 2013).

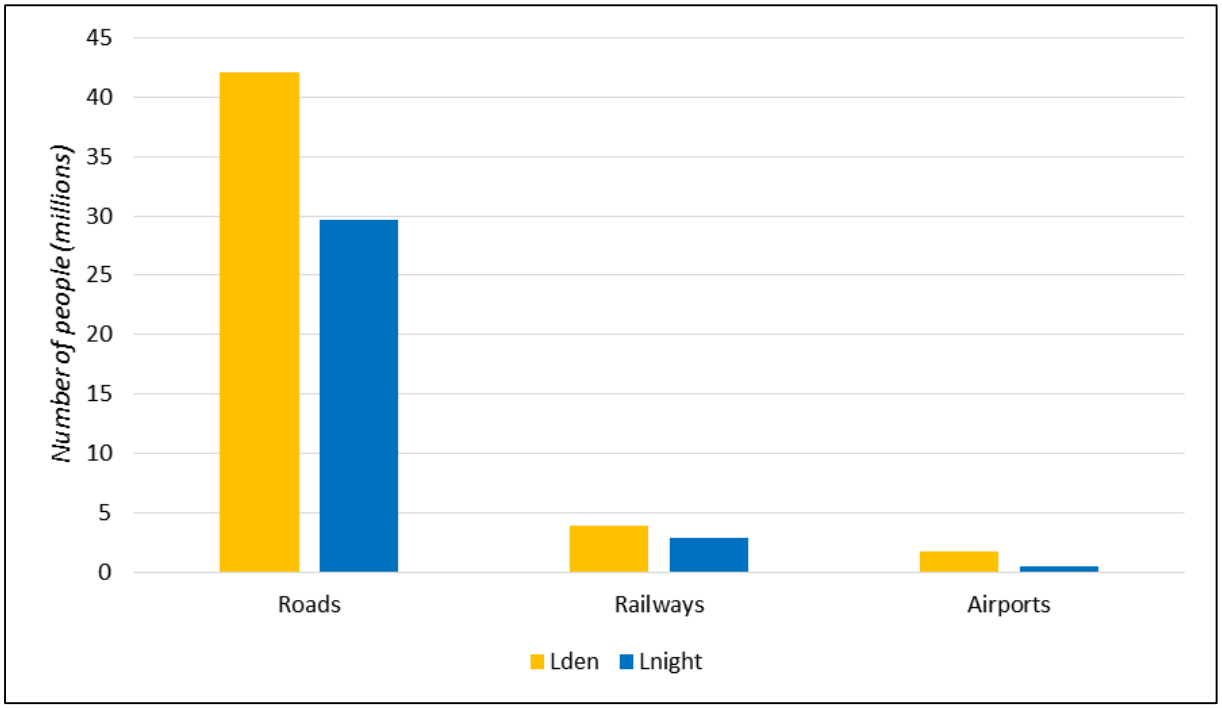

Figure 7. Number of people in urban agglomerations exposed to transport noise in 2013[3] (EEA 2014b)

Air pollution

The Environmental Protection Agency (EPA) introduced the "National Air Quality-Standard" for particulate matter (PM) in 1987. In this context, PM_{10} describes the category of particles with an aerodynamic diameter less than 10 µm, which are primarily the product of anthropogenic sources such as transport, power and heating plants, waste incineration plants, heating systems, bulk handling, and certain industrial processes. When breathed in, these particles can reach the deepest regions of the lungs, and are therefore considered as most harmful to health (Umweltbundesamt 2015).

Lisbon experienced only slight reductions in the PM_{10} level measured at the traffic station *Avenida da Liberdade* between 2008 and 2012. The EU target of 35 days per year for exceeding the PM_{10} limit values has not been complied in 2008 (82 days) and in 2012 (79 days). 2014 was the first year Lisbon seemed to meet the EU target, but only due to favorable meteorological conditions (BUND 2014). The limits for NO_2, a toxic gas arising from the combustion of fossil fuels, such as gas, coal and oil, were breached in 2014 in Lisbon and, according to prognoses, this trend will most likely continue in 2015 (BUND 2014).

[3] *Lden*: Environmental Noise Directive indicator for day, evening and night level; *Lnight*: Environmental Noise Directive indicator for night level. Based on data reported by countries by 28 August 2013.

Traffic congestions

The problem of traffic congestions affects in particular the municipality of Lisbon, since it is the city with the highest demanded infrastructure. Due to the concentration of employment and education in the center of the town, the municipality is facing high amounts of commuting traffic through a small number of highways every day. These highways distribute the immense flow of vehicles to a low set of narrow roads, which is hardly expandable by reason of the hilly landscape. Increasing road traffic therefore regularly leads to inner-city congestions in traffic volume peaks (Anciaes 2015). The municipality of Oeiras, which is also home to a high concentration of companies, can better handle traffic peaks, since its infrastructure is modern and well established.

Traffic jams are not only a source of stress and reduced life quality in cities though. Additionally, they result in high financial expenses affecting both, individual households and economies. Recent studies predict the costs of traffic congestions in the U.S., U.K., France, and Germany to rise to $293.1 billion by 2030 (INRIX 2015). A shortage of parking spaces is a further consequence of the increasing traffic volume.

Traffic accidents

An additional negative effect of the increasing transport is the high number of traffic victims, injured or killed each year. Lisbon represents the municipality with the largest share of accidents caused by road traffic in Portugal with 21 percent in 2010 (INE 2011). This affects in particular less wealthy inhabitants, since the used cars driven by this ethnic group are often badly maintained and thus less safe compared to new vehicles, which naturally increases the risk and severity of accidents.

2.2.3 Global Effects of the Problem

The high demand for fossil fuels, which is accompanied by the increasing traffic, is nowadays more than ever closely linked to the problem of rising emissions. The operation of different modes of mobility requires energy, in the transport sector mainly obtained by petroleum based non-renewable resources. This is particularly problematic in view of the natural limitation of the raw material oil and the greenhouse gas emissions. Carbon dioxide (CO_2), arising with the burning of fuel, is one of the so-called “greenhouse gases” (GHG), which take direct influence on the earth’s climate (Bosch, Colijn 2010). In this context, global warming plays a central role, especially in the light of urban “heat islands”, defined as built-up areas that are hotter than nearby rural areas. The increasing transformation of fertile into built-up land is regarded as the cause of problems with peak energy demands in summer, air conditioning costs and heat-related illness. Studies have proven that global warming further intensifies these issues (EPA 2015).

The relevance of CO_2 reductions is also expressed by the ocean acidification, which could lead to an extinction of many animal and plant species. This would directly affect the marine food chain, fishing and hence the human living on earth (Schröder 2013). As outlined in Figure 8 on the following page, the

transport related GHG emissions in Portugal have significantly risen by 65 percent in the period from 1990 to 2012.

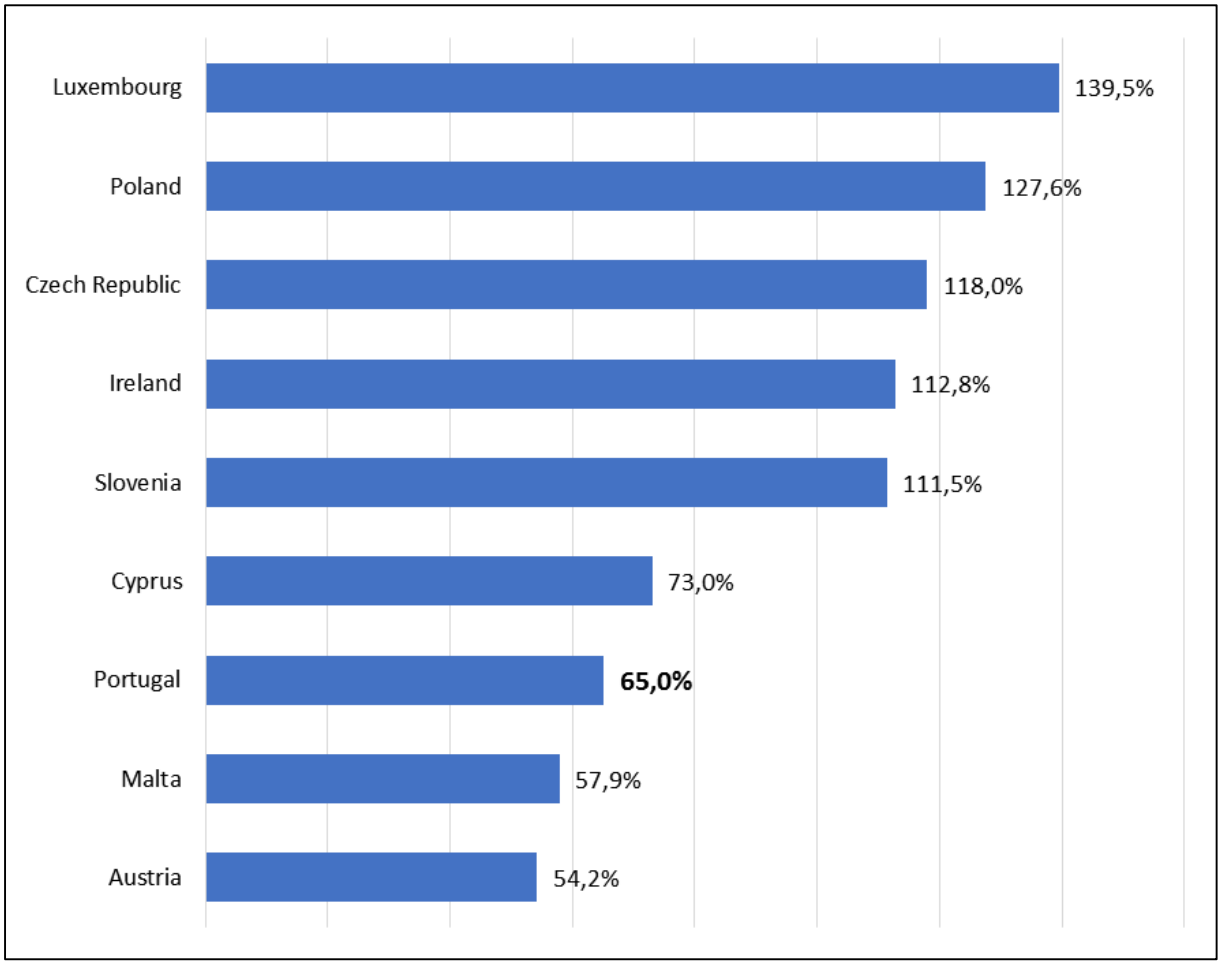

Figure 8. Change in total GHG emissions from transport (1990 to 2012 [EEA 2014a])

3 Theoretical Background

After the key causes and effects of the increasing traffic volume in Greater Lisbon were identified and analyzed, a mobility related product-service system, namely car sharing, will be investigated from the point of view of sustainable development in the following sections. Therefore, it is first necessary to elucidate the three terms “sustainability”, “sustainable development”, and “product-service system”, as well as to highlight the interrelations between them.

3.1 Sustainability and Sustainable Development

Sustainability, or sustainable development, is one concept that has different definitions and meanings, depending on the area of application and on the different contexts (Weaver et al. 2008). One definition widely accepted and drafted by the *World Commission on Environment and Development* within the *Brundtland Report* in 1987 (WCED 1987) states that “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In accordance with the quotation, sustainable development is seen as a development that satisfies the needs of present generations without, however, having negative impacts on future generations. Despite existing differences between sustainability and sustainable development, the two terms are considered as equivalent in the scope of the present dissertation.

3.1.1 The 3 Dimensions of Sustainable Development

In the last few years, sustainability was increasingly conceptualized as three overlapping circles representing ecological compatibility, social justice and economic efficiency (Weaver et al. 2008).

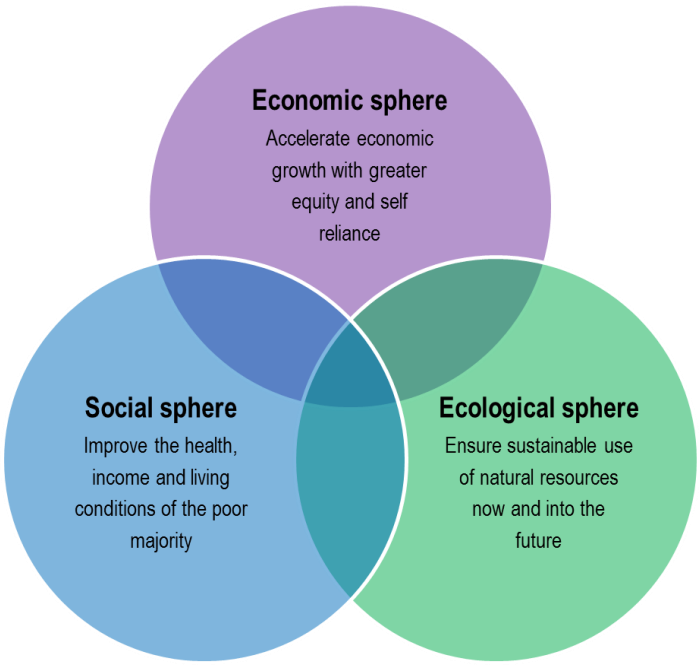

Figure 9. The three dimensions of sustainable development (Weaver et al. 2008)

Figure 9 illustrates the idea of three interrelated dimensions constituting sustainable development. As evident in the figure, there is an intersection between these three “spheres” (sustainable development is at the center of the cross-relationship), which means that they interact with each other, so that sustainable development can only be implemented successfully, if they are considered together as part of the same effort (Hale and Lachowicz 1998).

Academic and political debates about the content-related design and the practical implementation of sustainable development are primarily concerned about the different emphasis placed on the respective dimension (BPB 2008). In the following, two different approaches to sustainable development adopted by the European Union and the United Nations (UN) are analyzed respectively with a focus on transportation.

3.1.2 The EU Sustainable Development Strategy

The first *EU Sustainable Development Strategy* (EU SDS) was already launched in June 2001 as a reaction on existing unsustainable trends in many areas within the European Union. The major goal of the strategy was, according to European Commission (2015), to improve quality of life through “the creation of sustainable communities able to manage and use resources efficiently, able to tap the ecological and social innovation potential of the economy and in the end able to ensure prosperity, environmental protection and social cohesion”. One of the key challenges is dedicated to sustainable transport and comprises the following targets (Eurostat 2015b):

- Decoupling economic growth and the demand for transport with the aim of reducing environmental impacts.
- Achieving sustainable levels of transport energy use and reducing transport greenhouse gas emissions.
- Reducing pollutant emissions from transport to levels that minimize effects on human health and / or the environment.
- Achieving a balanced shift towards environment friendly transport modes to bring about a sustainable transport and mobility system.
- Reducing transport noise both at source and through mitigation measures to ensure overall exposure levels minimize impacts on health.
- Modernizing the EU framework for public passenger transport services to encourage better efficiency and performance.

Eight years later in July 2009, the European Commission adopted a review of the EU SDS, which underlined the introduction of sustainable development into a broad range of its policies (European Commission 2015). Despite these efforts, the transport sector is not yet sustainable in the European Union and transport activities have negative environmental impacts on both, local and global scale, as revealed in the chapter of the problem analysis (compare Chapter 2).

3.1.3 The 2030 Agenda for Sustainable Development

A more recent approach adopted by the United Nations in August 2015 expresses the "mission" of sustainable development via seventeen sustainable development goals (SDGs), defined within the *2030 Agenda for Sustainable Development* and further divided into 169 sub-objectives. According to UN (2015), these goals and objectives seek to "stimulate action over the next 15 years" in the areas of people, planet, prosperity, peace and partnership, since these issues are "of critical importance for humanity and the planet". The following section reveals the transportation-related sustainable development goals formulated by the United Nations based on UN (2015), and aims at highlighting the currently existing contradictions to the in Chapter 2.2.2 and 2.2.3 identified environmental problems caused by mobility.

If the goals of the *2030 Agenda for Sustainable Development* are taken into consideration, as they are depicted in Annex 2, a strong interlinkage (direct / indirect) to the road traffic is clearly recognizable in goal 3 as well as in goal 11 to 15. The concrete contents of these goals are as follows:

Directly linked to road traffic

- Goal 3. Ensure healthy lives and promote well-being for all at all ages.
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
- Goal 12. Ensure sustainable consumption and production patterns.
- Goal 13. Take urgent action to combat climate change and its impacts.

Indirectly linked to road traffic

- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forest, combat desertification, and halt and reserve land degradation and halt biodiversity loss.

There are obvious conflicts with the transport sector nowadays in many European countries. If the example of Portugal and Greater Lisbon is considered, as it was analyzed in Chapter 2.2, the large number of road accidents, road congestions, air pollution and noise, triggered by the increasing traffic volume should encourage trend changes, especially in the light of safe and resilient cities and human settlements up to 2030, as it was formulated by the United Nations in goal 11. To halve the number of global deaths and injuries from road traffic accidents by 2020 is also a sub-item of goal 3, which should be prioritized in the coming years, especially in light of the problem analysis.

The efficient use of natural resources, as it is stipulated in goal 12, is far from reality yet, if the high consumption of raw materials, like aluminum or steel, in the construction phase of automobiles, and the high consumption of petroleum based resources in the use phase are taken into consideration.

Global warming and ocean acidification are largely the result of the transport sector (compare Chapter 2.2), since these two phenomena are triggered by the high emissions of greenhouse gases, which goes contrary to the action to global climate change conserve and sustainable use of the oceans described in goal 13 and 14, especially if the increasing number of car registrations in Portugal is taken into account.

After the insights that landscape fragmentation caused by roadmaking is in particular responsible for the decline of animal and plant species, the increasing traffic in urban areas goes even contrary to goal 15, the protection of terrestrial ecosystems.

3.2 The Product-Service System Framework

Since today's road traffic clearly infringes several goals of the United Nations *2030 Agenda for Sustainable Development,* it is obvious, that transport in the EU is not yet sustainable. After the foundations for an understanding of sustainable development were laid in the previous section, the following deals with a concept that emerged in the late 1990s in The Netherlands and is nowadays often seen as a new approach to sustainability – the so-called "product-service system" (Szwejczewski et al. 2015).

According to Manzini and Vezzoli (2003), a product-service system (PSS) can be defined as "the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services, which are jointly capable of fulfilling specific client demands". Manufactures nowadays tend to move from the traditional production and sales of products to the provision of services. Tangible artifacts, the products, and intangible services are conflated through design processes and jointly capable to add value to the customer. The key components of PSS, the tangible artifacts, are often subordinate to the service element (Cook et al. 2006).

It will become apparent later that this new way of interacting with clients allows companies to satisfy customer needs with less environmental impact, by using significantly fewer resources. Thus, former pure product manufacturers, like Dell or General Electric, nowadays generate greater profitability from their service operations (Yoon et al. 2012).

3.2.1 Typology of Product-Service Systems

According to Yoon et al. (2012) and Cook et al. (2006), PSS can be divided into three categories, as shown in Table 1 and described hereafter:

I. A *product-oriented* PSS, where the ownership rights of the product are transferred to the customer, and in addition to the product a service arrangement is provided (e.g. maintenance or warranties).
II. A *use-oriented* PSS, where the ownership of the tangible product is retained by the service provider, who sells only the functions related to the product (e.g. leasing or sharing).
III. A *result-oriented* PSS, where the product is owned by the service provider; the customer purchases the utility as an outcome, not as the use of the product (e.g. clean cloth delivered through a washing service).

Table 1. The three categories of PSS (Yoon et al. 2012)

Components	Description
Product-oriented PSS	Highlighting the role of products with the support of additional services
Use-oriented PSS	Focusing on valuable use of existing products in different ways
Result-oriented PSS	Concerning the agreement of the desired outcomes without the involvement of specific products

3.2.2 Sustainable Product-Service Systems

PSS are not necessarily linked to sustainability. They only have the potential to contribute to sustainable solutions, if they assist in re-orienting current unsustainable production processes or consumption patterns in all three dimensions of sustainability in an integrated way. However, the fundamental characteristics of PSS lend themselves to the potential of more sustainable solutions, since they consider the product life cycle from a more holistic point of view (Manzini and Vezzoli 2003). In a traditional market, the different stakeholders (like raw material and energy suppliers, producers, retailers, consumers) integrated in the product life cycle framework tend to optimize their segment of the process discretely, due to the fact that they operate as separate entities (see the inner arrows of Figure 10). PSS, in contrast to traditional manufacturing concepts, aim at achieving an integrated functional solution instead of a “simple” product to meet the customer needs. For this reason, the efficiency efforts shift from discrete to system resource optimization (see the outer ring of Figure 10).

Manzini and Vezzoli (2003) write that by this holistic life cycle approach, synergies can be gained in the areas of profit, competitiveness, and environmental benefits. During the use-phase, the producer has an economic interest in keeping the products' operating costs low, since the profit depends on the cost per unit of the service provided. Low costs can only be achieved by reducing the amount of resources consumed and maintenance required, which promotes the development of energy efficient and robust products. Since the producer remains the owner of the product, he is furthermore interested in extending the product lifetime in order to postpone both, disposal of the old, and manufacturing costs of the new product (Vezzoli et al. 2015).

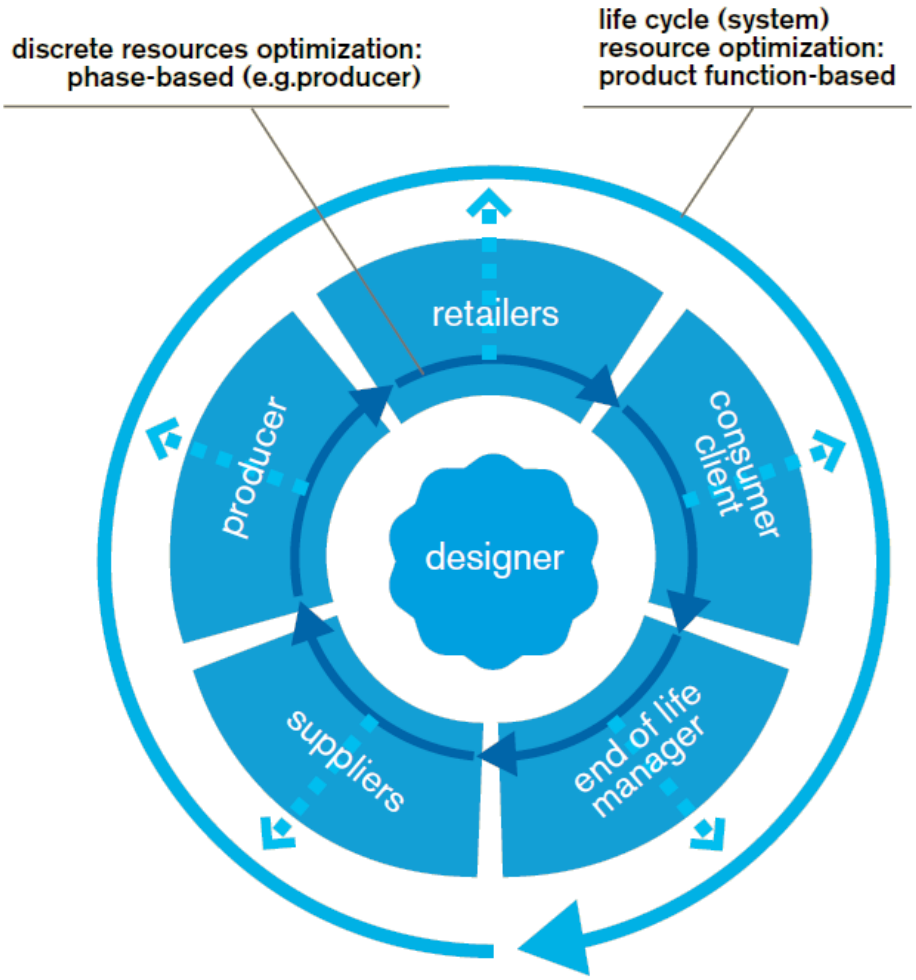

Figure 10. Discrete vs. system resources optimization (Manzini and Vezzoli 2003)

If the three-sphere model of sustainable development is recalled (compare Figure 9), the contributions on sustainability achievable by PSS business models can be divided in three categories – ecological, social, and economic. An overview of potential PSS contributions assigned to each sphere is given in Table 2. However, one should bear in mind that there is an interlinkage between the three spheres, and that sustainable development is located at the center of the cross-relationship. Thus, most of the factors contribute to more than one sphere, e.g. "increasing customer loyalty" could also be attributed to the ecological sphere. A three-stage classification is therefore only sensible to a limited extent.

Table 2. PSS contributions on sustainability (Hu 2013)

Ecological Sphere	Social Sphere	Economic Sphere
Reducing waste	Creating new job opportunities	Increasing customer loyalty
Saving resources	Reducing financial stress	Encouraging innovation
Improving recycling activities	Increasing the user satisfaction	Sustaining competitiveness
Increasing energy efficiency	Accessing new technologies	Avoiding costs of recycling

3.2.3 Mobility as a Product-Service System

Mobility is an expression of human needs and a basic requirement for economic growth. Since the development of the automobile, individualization in mobility has steadily increased in the passenger transport, as the problem analysis (compare Chapter 2) has clearly revealed. The share of passenger cars in the passenger transport modal split within the EU-28 climbed to 72 percent in 2012, though, not only due to growing mobility needs. Indeed the automobile is today still a status symbol in many cultures (Klasing 2006).

However, there are signs of change recognizable in certain European countries, especially in Northern European countries. In these nations, the focus of younger generations' currently shifts to just satisfying needs instead of possessing the physical product, not only in terms of mobility. Hence, the meaning of cars as expression of status and prosperity is becoming less and less important (Shimomura and Kimita 2013).

Nevertheless, vehicles remain important, since mobility is a demanded attribute and flexibility is seen to be much more essential to life in today's modern age (DPA 2010). Therefore, in contrary to traditional automobile manufacturers, providers of transport-related product-service systems shift their business from selling vehicles towards the offering of a product-service combination, namely mobility, to the customer (Shimomura and Kimita 2013). Thus, the profitability of these enterprises is no longer a product-selling matter, instead the utilization rate of the product offered shifts in the center of interest (Kriston et al. 2010). Car sharing, which falls in the category of use-oriented PSS (compare Table 1), has "relatively recently paved its way into the list of possible solutions to transportation-related problems", according to Kriston et al. (2010), but offers a highly promising approach to contribute to sustainability. By the use of car sharing, negative environmental impacts can be reduced by 30 percent, according to studies on environmental impacts of PSS (Shimomura and Kimita 2013), which has to be further analyzed in the framework of the present dissertation.

In the following chapter, the concept of car sharing is elucidated first. Afterwards the dissemination in Europe is investigated and the potential contributions to the three spheres of sustainability are examined. Subsequently, the main barriers towards car sharing are identified and European experiences with car sharing in countries different to Portugal, but with comparable culture are analyzed, in order to draw first conclusions on the expected social acceptance of car sharing in Greater Lisbon, and to derive generic success factors.

4 Car Sharing as an Emerging Practice in Europe

4.1 Definition and Delimitation of Car Sharing

There is no single correct definition of car sharing, since the terminology has never been standardized. Consequently, varying definitions can be found. Table 3 gives an overview of the ones found in relevant literature. What all these definitions have in common, is that the term “car sharing” refers to a service concept that organizes the access to motor vehicles, which are shared among members with mobility needs.

Table 3. Definitions of car sharing

References	Definitions of car sharing
(Millard-Ball et al. 2005)	“[…] a service that provides members with access to a fleet of vehicles on an hourly basis.”
(Baptista et al. 2014)	“[…] a membership-based service that offers the user short term vehicle access, when other modes of transport are not available or are not convenient.”
(Le Vine et al. 2014)	“[…] a mobility service that draws on modern technology to enable access to car-based mobility without the consumer owning the physical asset (a car).”
(Yoon et al. 2012)	“[…] a typical use-oriented PSS, where users can reserve cars when they need them and pay automotive expenses on a variable basis (e.g. per kilometer or per unit of time).”

The diversity amongst different types of car sharing schemes is large and, in some cases, one operator delivers more than one service model (Le Vine et al. 2014). In principal, three kinds of car sharing variations can be distinguished, as presented below according to Collaborative Fund (2015):

- *P2P* (peer to peer):
  A community owns a fleet of cars and the marketplace matches owners of cars that are available to other drivers to rent.
- *NFP* (not for profit):
  A local organization or community that facilitates car sharing with the goal of changing driving habits over making a profit.
- *B2C* (business to consumer):
  A company owns a fleet of cars and facilitates the sharing amongst members.

B2C car sharing is closely linked to the concept of (use-oriented) PSS, which was described in the previous chapter. According to Le Vine et al. (2014), B2C car sharing is referred to mobility services with the following characteristics, which also clarify the differences to traditional rent-a-car offerings :

- The user must go through a pre-qualification of ID and driving record and is then able to access the service's car autonomously (keyless access is typical).
- The vehicle is driven by the end user.
- Usage is typically billed in time increments of minutes or hours.
- There may be a one-time sign-up fee or an annual subscription fee.
- Usage is in some cases spontaneous and in others reserved in advance.
- The vehicles are normally available from distributed locations across a service area.
- Servicing / cleaning is done by the operator's staff on an occasional basis, rather than after each usage.

The focus of the dissertation is on B2C car sharing, since this sector offers the highest potential to substitute the private car in the long term. Instead of (or in addition to) possessing a private vehicle, consumers hire passenger cars from businesses, mainly represented by automobile manufacturers, rental brands or autonomous car sharing brands, and pay per hour of the service used (Collaborative Fund 2015).

B2C car sharing concepts can be further subdivided in two concepts, which are described in the following section based on BUND (2015), and Le Vine et al. (2014).

Station-based

Station-based car sharing is characterized by fixed rental and return stations. Users typically pick up a vehicle from a parking station and return it to another. The stations usually offer fixed infrastructure, like charging points for electric vehicles or kiosks for customer services. Typical elements of a station-based car sharing concept fall into the categories of physical objects (e.g. cars), service units (e.g. stations), and organization (e.g. number of stations), as depicted in Figure 11. To enable a correct operation it is crucial to clarify the limits, relations and frontiers between these elements (Shimomura and Kimita 2013).

Main advantage of fixed stations is the ease of management, since logistics are less challenging in comparison with free-floating car sharing services. However, the provided degree of flexibility for the user is slightly lower.

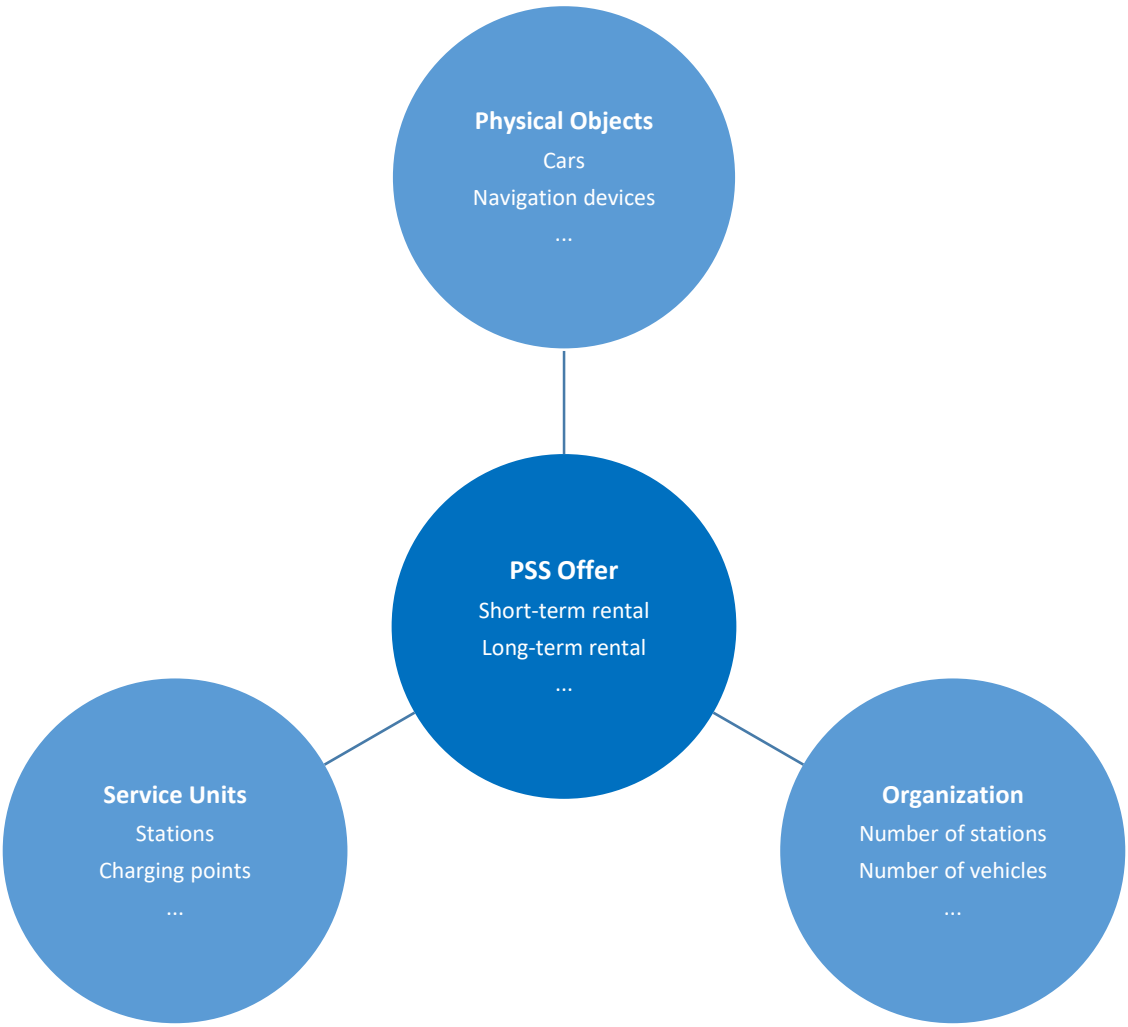

Figure 11. Example of PSS elements in car sharing (Shimomura and Kimita 2013)

Free-floating

Free-floating car sharing offerings allow the user to spontaneously access parked vehicles in the operators' geographic zones – reservations are usually not provided. After the vehicle rental, cars can be left in freely accessible locations, which requires a contractual agreement between the car sharing operator and the entity that manages the on-street parking. Free-floating offers a higher degree of flexibility, but the operating and rental costs are marginally higher than in station-based car sharing.

For traditional station-based car sharing, positive environmental effects are proven and mentioned in different literature (Firnkorn and Müller 2011). However, free-floating services are only hardly comparable to traditional concepts and were facing some critics, since they are in direct competition with local public transport systems and taxis (BUND 2015).

4.2 Dissemination in Europe

Switzerland is the historical cradle of the car sharing concept – the so-called "Selbstfahrergemeinschaft", which was operated from 1948 to 1998 in Zurich, is seen as the global pioneer. The original idea behind the concept was to share one car among members, which would not be able to afford it alone. Larger car sharing projects first started in the seventies and early eighties in Europe, Japan and the USA (NZZ 2007).

In the meantime, car sharing operators are spread over many European countries, and this growth is likely to continue for some time, since the market potential has not yet been fully exploited by any means. According to current forecasts of the consulting company *Frost & Sullivan*, the global number of car sharing users will climb to 15 billion in 2020 (Schlesiger 2012). At the present time, the largest provider of car sharing services is the German car manufacturer *Daimler AG* with its subsidiary *car2go*. In 2014, *car2go* had one billion customers and 12,500 vehicles in 30 cities worldwide (Car2go 2014).

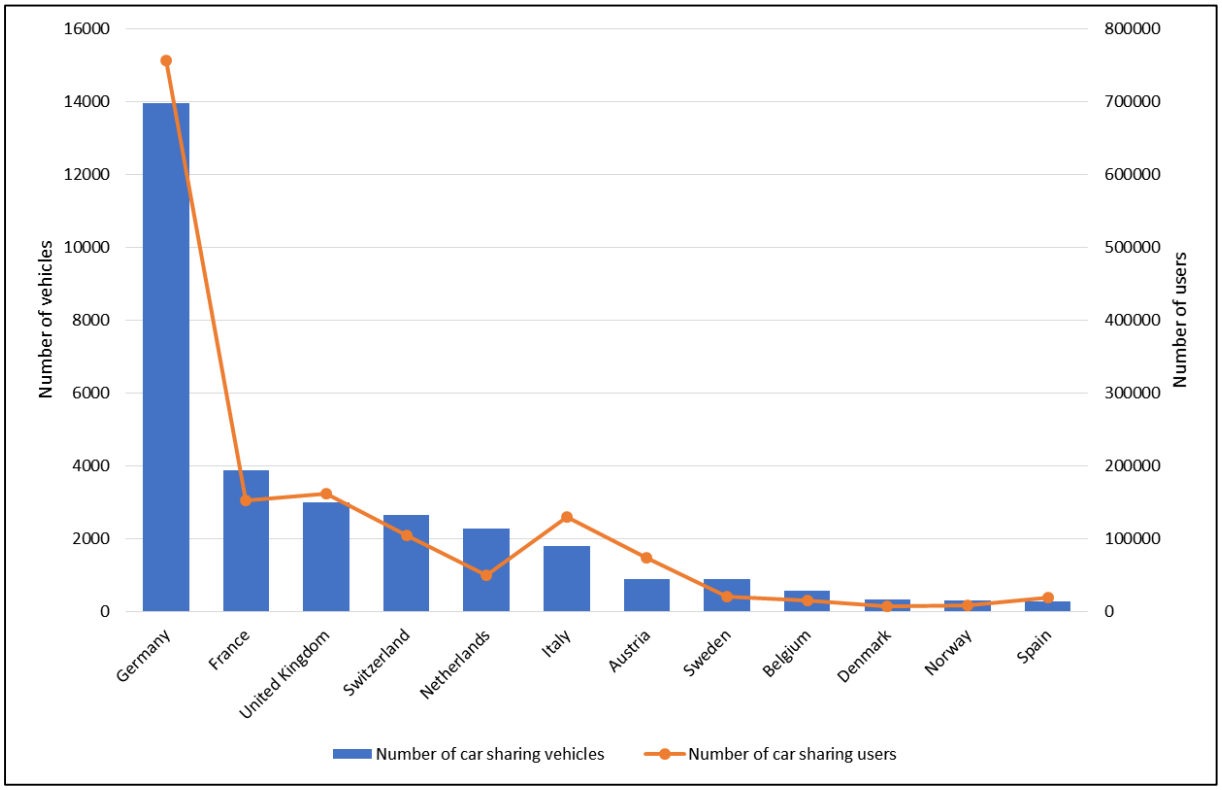

Figure 12. Number of car sharing users and vehicles in European countries (Frost & Sullivan 2014)[4]

If the current numbers of car sharing vehicles and users are taken into consideration, as it was done in Figure 12, Germany takes the first place in Europe with around 14,000 vehicles used by 760,000 members, followed by France, the United Kingdom, Switzerland and The Netherlands. It is conspicuous, that the only represented Southern European country amongst the top ten regions is Italy. The other

[4] Data is based on car sharing operators

Southern European country listed is Spain in twelfth place, which represents merely a small market with 300 car sharing vehicles and 20,000 users, despite the relatively large population. Northern European countries, such as Denmark and Norway, are depicted in the graph, regardless of their relatively low population in a European comparison, which clearly shows the acceptance of shared car usage in those countries. The car sharing market of Italy is analyzed in more detail in the later stages of the dissertation, since the public authorities in this country have provided the right incentives to increase car sharing availability. Additionally, the car sharing market of Spain is investigated, due to the geographical proximity and existing similarities to Portugal.

4.3 Effects of Car Sharing

Changes in consumption patterns are difficult to influence, especially in terms of products with attached social meanings like automobiles. Thus, the move away from individual car ownership to shared use is a challenging task. Nonetheless, the chapters of sustainable PSS (compare Chapter 3.2.2) and mobility as a PSS (compare Chapter 3.2.3) have indicated that it can be worth it, since the negative environmental impacts of traffic can be reduced significantly.

A simple search query with the terms “sustainability” and “carsharing” on the *Google Scholar*[5] website reveals that already several papers have been published on the subject sustainability of car sharing. These studies indicate that the use of such a product-service system may result in several positive effects on sustainable development (compare Table 4).

Table 4. Potential effects of car sharing

References	Potential effects on sustainability
(Briceno et al. 2005)	Car sharing programs are able to reduce the number of cars significantly.
(Rabbitt, Ghosh 2013)	Car sharing can offer reductions of travel related CO_2 emissions and can increase the share of sustainable modes of travel.
(Litman 2015a)	Households that share rather than own a car can reasonably save money on transportation.
(Firnkorn, Müller 2011)	Car sharing schemes can raise the city attractiveness through lower car traffic.

The basis of the following section is an in-depth review of relevant literature that shows that despite the improvement of transportation related problems, car sharing schemes indeed offer many advantages,

[5] Google Scholar is a freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines.

and can positively contribute to all three dimensions of sustainable development – social, economic and ecologic – in an integrated way.

4.3.1 Ecological

The ecological dimension of sustainable development considers nature and environmental conditions, in particular the preservation of biodiversity, climate protection, the maintenance of cultural and natural areas in their original form, and in general a careful handling of the natural environment. The commercial use of nature in the form of raw materials as well as the damage to the environment caused by exploitation and transport burden atmosphere and ecosystem, compromising future habitat and well-being (Hauff and Kleine 2014). Sustainable development aims at reducing these negative impacts on nature, while ensuring a high level of social and economic performance simultaneously.

As analyzed in Chapter 2.2.2 and 2.2.3, the evolution of road traffic is currently not in line with the intentions of sustainable development, particularly in light of goal 3, and 11 to 15 of the *United Nations 2030 Agenda for Sustainable Development* (compare Chapter 3.1.3). Passenger cars consume high levels of energy and emit pollutants in all three phases of their life cycle (construction, operation and decomposition). Landscape fragmentation is another negative effect resulting from the increasing road traffic, since the road network is continuously expanded in Europe (compare Chapter 2.2.2). Car sharing may play an important role in reducing these negative effects and may contribute to sustainable development in all three phases of a vehicle's life cycle, as elucidated hereafter.

Construction phase

The production of passenger cars requires large amounts of raw materials and energy. Consequently, if fewer vehicles are produced, less natural resources and energy is required in average in the construction phase. Recent studies point to the fact that car sharing leads to a reduction of the existing vehicle stock up to 40 percent, since the utilization rate of car sharing vehicles is significantly higher in comparison with private passenger cars (Briceno et al. 2005). This goes so far that, according to Briceno et al. (2005), car sharing vehicles "tend to be driven more than twice the distance of private cars with almost double the occupancy rate". And in fact, if the data behind Figure 12 is analyzed in detail, it can be concluded that one vehicle is shared by 44.5 users in average.

Operation phase

As already stated in Chapter 3.2.2, operators of PSS strive for keeping their products' operating costs low, since their profit mainly depends on the cost per unit of the product provided. Car sharing is a use-oriented PSS, and therefore the same rules apply: by reducing the amount of resources consumed by each car, overall profitability can be increased. This circumstance encourages energy-efficient vehicles and alternative drive systems, like electric or hybrid cars, within the operating fleets of car sharing providers. Hence, if the specific CO_2 emissions of car sharing fleets are confronted with the specific

national emissions of European countries, car sharing vehicles tend to emit 15 to 20 percent less CO_2, according to Loose (2010). This is particularly relevant in view of climate change and ocean acidification (compare Chapter 2.2.3). However, not only the circumstance that car sharing providers tend to lower their operating costs supports sustainable development, but also the fact that car sharing fleets generally show a relatively low average age and are well maintained. This leads, in addition to the above-mentioned reduction of GHG emissions, to a reduction of air pollution, since newer cars emit much less harmful CO, NO_X, SO_2, and particulates. Furthermore, the lower age and better maintenance of the fleets leads to a decrease in the loss of oil, which is a problem owners of older properties are frequently facing (Firnkorn and Müller 2011).

Another negative effect of road traffic, which can be positively influenced by the implementation of car sharing, is the noise pollution in urban areas. As analyzed in Chapter 2.2.2, large cities in Europe are increasingly struggling with noise, caused by transportation, and road traffic constitutes the major source of traffic noise according to city dwellers. Various studies have proven that car sharing users lower their yearly mileage travelled by car up to 43 percent, especially those who decided to substitute their private cars (Gossen 2012). Naturally, this circumstance leads to both, a reduction in noise and air pollution at the same time. The integration of alternative drives in car sharing, such as electric vehicles, obviously enforces this positive effect, since noise emissions tend to be considerably lower.

If the traffic-related landscape fragmentation, as it was analyzed in Chapter 2.2.2, is taken into consideration, positive contributions of car sharing are also easily recognizable. By the shift from private car ownership to shared use, the number of cars produced decreases, as mentioned before. Therefore, the transportation related static land use may be decreased as well, since the area for parking spaces and infrastructure required in municipalities could be diminished, according to Firnkorn and Müller (2011). Road congestions referring to the dynamic land use are lowered also, especially if, in addition to the decreased number of cars, the reduced yearly mileage travelled by car sharing members is considered.

Decomposition phase

Car sharing services are often provided by automobile manufacturers, which facilitates the recycling management as well as the closing of material loops. After the operation phase, raw materials can be directly re-introduced into the economic cycle. Especially in the light of scarce resources like lithium, car sharing concepts show clear ecological benefits in comparison with private cars, since raw materials are faster returned into the production process and are not bound in private cars for longer periods (Firnkorn and Müller 2011). Hence, the exploitation of natural resources is diminished.

An overview of the ecological parameters affected by car sharing based on Firnkorn and Müller (2011) is depicted in Figure 13, which distinguishes between the three process steps of the product lifecycle.

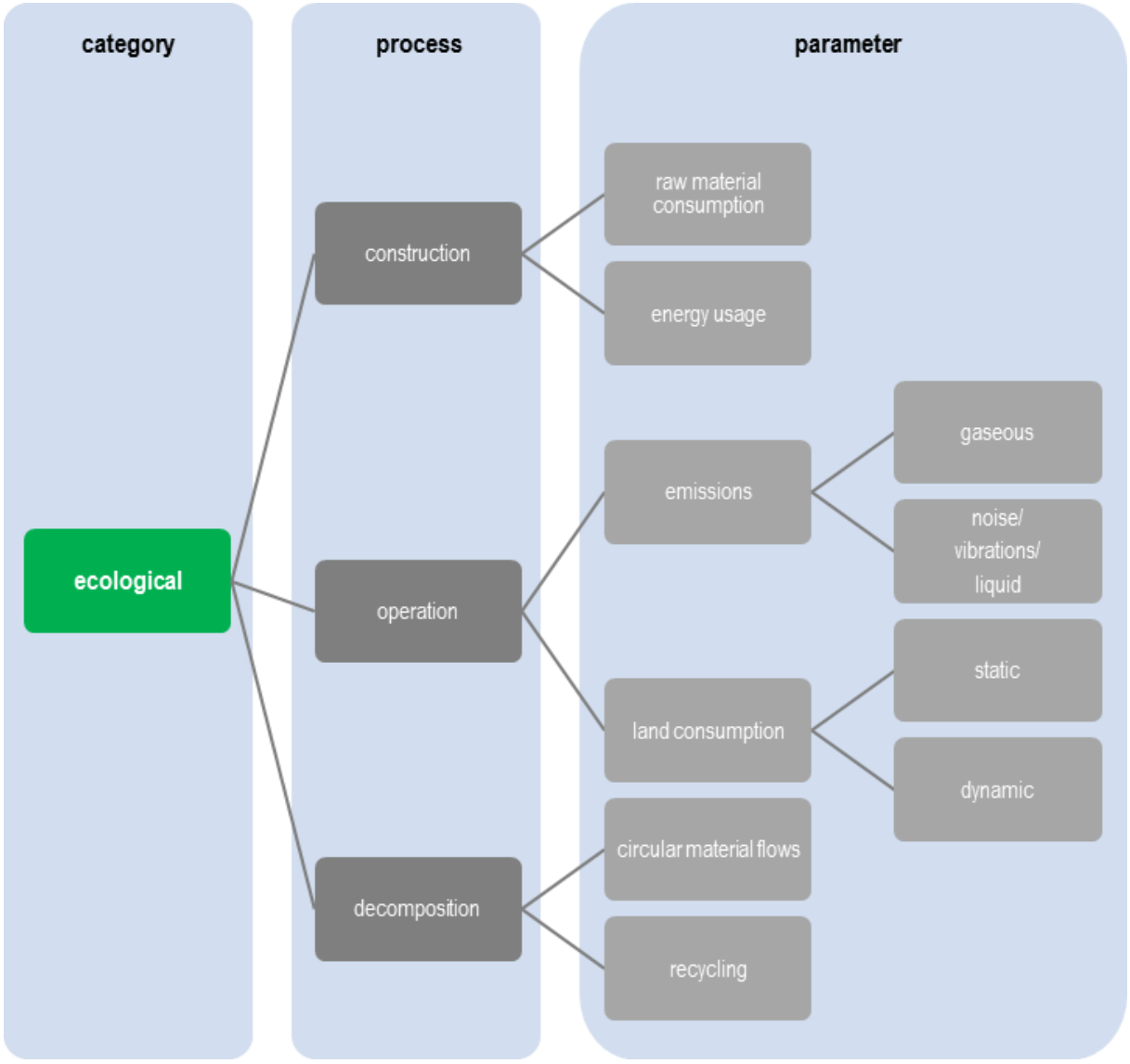

Figure 13. Environmental parameters affected by car sharing (Firnkorn and Müller 2011)

4.3.2 Social

The social sphere of sustainable development concerns itself with the question regarding distributive justice, which refers to the access of opportunities and resources within individual countries (BPB 2008). Car sharing models allow even less wealthy citizens the access to individual mobility, since, in contrast to private car ownership, no high initial investment is required, which may break down existing differences between distinct social areas. For instance, competitive disadvantages of non-drivers when competing for jobs and education can be decreased, since a high degree of geographical mobility is often a basic requirement and an important hiring criterion in today's society, especially in rural areas.

Furthermore, particularly for drivers with low annual mileages up to 5,000 kilometers per year car sharing can be worthwhile financially, even in comparison with used cars (Litman 2015a). The reason for this is

that the high fixed costs of car ownership (e.g. purchase, insurance, taxes) are attributed to a low number of kilometers, which results in high expenses per kilometer. However, the exact costs per kilometer of car ownership are versatile and therefore difficult to quantify, since they depend on several factors, like national tax system, insurance costs, annual mileage, maintenance costs, and so on. Nonetheless, a cost comparison between car ownership and car sharing will be shown in the later stages of the dissertation.

Despite cost savings and social equity, high satisfaction of car sharing members can be seen as a further contribution to the social sphere, which is based on the availability of various car models for different occasions (depends on the car sharing business model), usage flexibility, and a lack of maintenance responsibilities for the users (Mont 2004).

Furthermore, the raising city attractiveness for inhabitants and tourists, which is as well a major concern of goal 11 of the *2030 Agenda for Sustainable Development* (compare Chapter 3.1.3) can be reached by car sharing, since road traffic can be lowered significantly.

4.3.3 Economic

Within the scope of sustainable development, it has to be ensured that the economy is designed to provide a solid base for earnings and prosperity. Of particular importance is the protection against exploitation of natural resources, since they are seen as a common heritage of humanity with a shared right of access. Hence, the economic growth should be limited to a certain degree in order to allow future generations the same consumption possibilities to satisfy their needs. A sustainable integrated economy is therefore concerned about obtaining employment and income, while being innovative and competitive, using only the resources it can afford (Asheim 2007).

The introduction of car sharing brings various economic benefits for both parties – customers and businesses. According to Litman (2015a) and Firnkorn, Müller (2011), the most important cost related advantages of car sharing can be summarized as follows:

- Mobility for small businesses as a more cost efficient and flexible alternative to owning vehicles.
- Reduced expenses for households, since vehicle ownership is a considerable cost factor.
- Increased economic productivity by allowing job seekers the access to cars if needed for job searching and employment.
- High fixed costs, especially of cars with alternative drive systems, are spread among many users (economies of scale).

Further economic advantages for car sharing businesses result from the increased customer satisfaction, which was previously stated, since the customer loyalty increases as well. Especially automobile manufacturers may profit from a new, innovative, and attractive branch prospectively, since they possess the know-how and resources to easily and cost-efficiently launch car sharing solutions. Hence the potential decrease in car sales resulting from the higher utilization rate of the car sharing

vehicles may be (over-) compensated. Nevertheless, despite these economic achievements, the demand of natural resources is reduced in comparison with the production and operation of private cars, as mentioned before, which clearly shows the overlaps of the three spheres of sustainability: decreasing the consumption of natural resources leads to a reduced environmental impact and financial savings simultaneously. Thus, it should be highlighted that the principle of sustainable development, the equitable implementation of environmental, economic and social objectives is assured, since car sharing contributes to all three dimensions without however emphasizing one in particular. It can therefore be concluded that car sharing is theoretically able to deliver positive outcomes on the environment, while opening up attractive business opportunities for start-ups as well as established companies. This will be further investigated later with the example of the developed car sharing concept.

4.4 Barriers Towards Car Sharing

The previous chapter has clearly revealed that car sharing is indeed able to contribute to all three spheres of sustainability in an integrated way. However, the potential contributions to sustainable development alone are not sufficient to successfully implement a car sharing product-service system in a new environment, since one of the main barriers of developed countries is the shift towards “having a transportation need” opposed to “owning a vehicle”. Hence, prerequisite for a working and prosperous business model is, among others, the social acceptance and willingness of the inhabitants to use the service offered. However, despite the potential users’ perspective, there are other challenges attributable to the infrastructure and provider side. The non-governmental global research organization *World Resource Institute* has identified several barriers towards car sharing in emerging markets. The ones shown in the table below and separated into the categories potential users, infrastructure and business, also apply to several developed European countries, like Portugal.

Table 5. Barriers to car sharing (WRI 2015)

Category	Barriers
Potential users	Strong desire for car ownership and usage Unfamiliarity with car sharing services Price sensitivity
Infrastructure	Insufficient public transport Insufficient cycling infrastructure Limited parking for car sharing
Business	High capital investment Limited access to capital Potential competition from taxis

The barriers indicated in Table 5 may hinder the growth of car sharing on the one hand, but could lead to opportunities for the car sharing industry and the population on the other hand. The implementation

of a car sharing scheme could lead to a number of improvements in the areas of public infrastructure, access to individual mobility, and prosperity.

The following section aims at providing a sort of benchmark by analyzing the car sharing market of the neighboring country of Portugal, Spain, that has already gained first impressions with car sharing services. Additionally, Italy is analyzed, since it is currently the Southern European country with the largest car sharing market. In that way first conclusions regarding the social acceptance, and required governmental support of a car sharing service in Portugal can be drawn. The outcome of the benchmark section are the critical success factors required to promote the social acceptance, and to implement a valuable car sharing business.

4.5 International Experiences on Car Sharing

4.5.1 Italy

Italy represents the country with the highest number of car sharing users in Southern Europe, as already stated in Chapter 4.2 and depicted in Figure 12. The fact that shared car usage is socially accepted and relatively widespread inside national boundaries is based on several factors, such as inner-city charges on polluting vehicles (*Ecopass*), tolls on vehicles entering the cities, and on-street parking of car sharing vehicles (greater visibility) in Milan (Papa 2012). However, one fact that contributed the most to the increasing popularity of car sharing in Italy is a national coordination structure known as *Iniziativa Carsharing* (ICS). The initiative was promoted by the ministry of environment, and already started in October 2000 (Battarra et al. 2012). It results from a legislative decree and aims at “promoting the implementation of structural changes to permanently reduce the environmental impact of traffic, through the introduction of sustainable mobility solutions”, according to Battarra et al. (2012).

In particular, the far-reaching governmental support aims at (Loose 2010):

- Ensuring the development of the different car sharing services in the country’s most important cities in a unitary network.
- Guaranteeing professional standards of the service to the users.
- Promoting the awareness of car sharing all over the country.
- Ensuring a full interoperability among all the different local services and operators.

According to ICS (2015), the major goal of the initiative was “to open up the market to as many economic operators as possible, but at the same time guaranteeing coherence in the global project”. In other words, the government prompted the local communities to launch car sharing services. The organization of these start-ups was left up to the local communities. Thus, many car sharing operators are in the hands of local authorities or public transport providers nowadays in Italy. This fact leads to certain advantages for the users, since they have access to low emission zones and free parking in city centers,

and can furthermore use the public bus lanes (Loose 2010). To comply with the standards required and to ensure system coherence, ICS currently supports local authorities with the provision of (ICS 2015):

- Technical design, legal, and administrative assistance
- Technology for running the service (on board computers, center equipment, communication links, assistance, etc.)
- Call center / contact center for customer services
- Communications, promotion, marketing services

The extensive government support has led to a steeply increasing number of car sharing members and vehicles in Italy, which accounted 130,000 and 1,800 respectively in 2014 (Frost & Sullivan 2014). These figures clearly show that public interventions may be justified and helpful to stimulate public interest, and to offer attractive market conditions, as well as a stable political and economic environment for investments.

Nonetheless, there are still strong differences (e.g. number of car sharing users and vehicles) to other European countries like France, Great Britain or Germany, which result from the "older" and much more developed car sharing service in these nations (Battarra et al. 2012).

4.5.2 Spain

By international comparison, the car sharing market in Spain is still relatively small, but slight growth is recognizable in the period from 2009 to 2014. In 2009 there was only one car sharing provider, serving the Barcelona region with 2,500 customers and 127 vehicles (Loose 2010). In 2014, car sharing businesses were already operating in the two biggest urban agglomerations of Madrid and Barcelona, as well as in Bilbao and Seville. In 2015 the largest global car sharing operator, *car2go*, successfully entered the Spanish market and established its first facility in Madrid (Car2go 2015). Since a deep and time-intensive market research prior introduction is inevitable, this fact clearly reflects that international operators see Spain as an attractive market for expansion in the meantime.

Nevertheless, car sharing services did not make it to the center of society yet, which is based on different factors. On the one hand, a survey conducted by BCS[6] in 2010 revealed that the national political and legal conditions for car sharing providers in Spain are barely fair. On a scale ranging from 1 (very good) to 5 (poor), car sharing operators evaluated the governmental support with 4 (Loose 2010). Italy appreciably outperformed Spain in this category, thus reflecting the success of the *Iniziativa Carsharing*.

On the other hand, automobiles were still important status symbols in the last few years, even more than in other European countries. Therefore, especially large, fast and heavy cars were in high demand

[6] *Bundesverband CarSharing e.V.*: industry association of the traditional car sharing organizations in Germany, which represents the political interests of the car sharing industry on a regional and national level.

in the last decades. The financial crisis, however, was accompanied with a rethinking in Spain. While motorcycles and cars are still expression of prosperity nowadays, the Spaniards had to make the experience that driving first of all costs money and pollutes the environment (Rose 2015). Shared usage, especially in terms of transport, therefore shifts further and further into the center of public interest, which is also reflected by the launch of *car2go* in Madrid in 2015. A further increase of car sharing solutions is consequently likely to happen in the next decade.

4.6 Success Factors of Car Sharing

The examination of the current market situation in Italy and Spain has revealed that Southern Europe still has a considerable backlog of car sharing services (relative to the population), which is, among other things, based on cultural differences to Northern European countries, in which the culture of sharing is stronger entrenched. However, especially the political decision-makers in Italy already implemented effective approaches to promote the public awareness and to improve the market conditions and thereby open up the national economy for car sharing companies.

This section aims at summarizing the previously identified success factors for car sharing services, as well as gaining impressions on what further necessities are. For this purpose, a phone interview with an American employee working for *car2go* in Germany was conducted within the framework of the dissertation. William Knapp, who is in charge for leading *car2go* operations throughout North America, answered on the questionnaire, represented in Annex 3. Thereby it was possible to confirm and explore various requirements necessary for a successful implementation of a car sharing business.

In summary, the following factors were identified within the research and the conducted phone interview:

- Adequate population and population density
- Political stability
- Suitable demographic characteristics (main target group young adults and families)
- Social acceptance of shared usage
- Adaptable parking rules and availability of parking space
- Agreements with local municipalities
- Availability of charging infrastructure for electric vehicles
- Government regulations and support

To what extend these requirements are fulfilled in Greater Lisbon has to be deeply investigated in order to be able to suggest an own car sharing solution and to evaluate if such a business model could have success.

5 Method

5.1 Research Design

In this section, the method elaborated and adopted in the framework of the present master's dissertation is described, before starting the practical part of the dissertation. Figure 14 represents a schematic overview of the research design, which is broken down hereafter.

The research process started with the identification of the problem – the increasing traffic volume in Greater Lisbon – followed by a comprehensive problem analysis, which is reflected by the introduction (compare Chapter 1), and the analysis of environmental problems caused by mobility in Lisbon (compare Chapter 2) of the dissertation. For this purpose, a *mind map* as well as a *cause and effect diagram*, which is depicted in Annex 1, was applied and used to identify the traffic related environmental issues, and the specific interrelations between them.

The subsequently following literature review started generic with focus on the research area sustainability (compare Chapter 3.1), and was afterwards specified on the field car sharing from the point of view of sustainable development and avoiding the negative effects of traffic. This literature review in conjunction with the *car2go* interview has led over to the chapter "Car Sharing as an Emerging Practice in Europe", and both serve as a basis for the argumentation in the dissertation, in which the research question is addressed.

The information acquisition in the practical part of the dissertation is as well based on interviews and surveys, but in this case the focus is on the potential users of the car sharing service, which are the inhabitants of Greater Lisbon in the present case. In particular, the expected value, the intention to adoption, and the preferred use of service are investigated from a user's perspective. Furthermore, the location Greater Lisbon is analyzed in detail, in order to investigate if the local market conditions are in accordance with the previously identified success factors of car sharing. Based on the data gained in the market and customer analysis, own suggestions for a car sharing model can be worked out and the resulting concept can be evaluated afterwards. Thus, definite conclusions and final recommendations can be drawn.

The following paragraphs describe the approach followed in the framework of the customer and location analysis. Furthermore, a multi criteria sustainability assessment tool is developed, which will be applied later on.

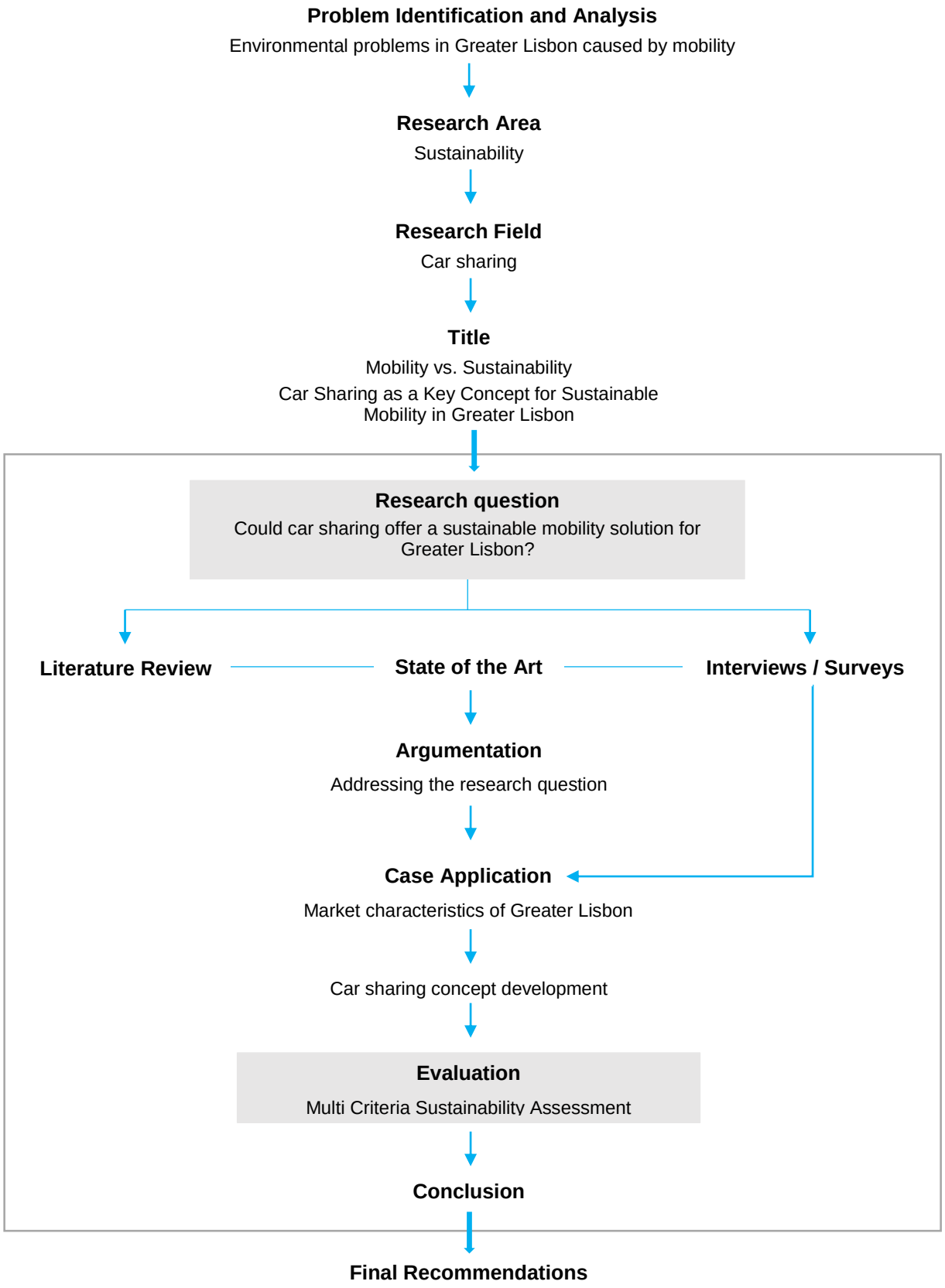

Figure 14. Research Design (Own graph)

5.2 Market Characteristics of Greater Lisbon

5.2.1 Customer Analysis

In order to evaluate the feasibility and potential success of a car sharing concept in Greater Lisbon, it was first necessary to investigate local culture and prospective customers' response and thoughts, which allowed drawing conclusions on the expected social acceptance of shared car use. The quantification of the willingness for mobility changes was obtained through a web-based survey, using the online survey software *SurveyMonkey*. To ensure a sufficiently large and widespread sample, and therefore most reliable results, the online survey was spread among the different faculties of the *University of Lisbon*. The target groups of the survey consisted of students, professors, researchers, as well as other faculty staff.

Furthermore, additional response from non-university individuals was obtained by distributing the survey to *facebook* contacts residing in Greater Lisbon.

Within the framework of the survey the awareness of car sharing was checked firstly, after the participant entered his or her personal data. Secondly, the principle of car sharing was elucidated by an example, in order to establish a uniform standard of knowledge. The survey was composed by 26 questions (compare Annex 4 to Annex 11), 23 close-ended and 3 open-ended, and covered aspects such as:

- Personal characterization
- Mobility patterns
- Awareness of car sharing
- Motivation to become a car sharing member
- Preferences concerning the service use
- Potential impacts of the service on travel behavior
- Benefits and disadvantages of car sharing (opposed to car ownership)

Additionally, the survey participants were asked about their travel mode use frequency, the proportion of single person trips by private car, and their average daily car usage. The survey questions are provided in Annex 4 to Annex 11.

The results obtained thereby are analyzed later on and are furthermore incorporated in the development of the car sharing concept, in order to design a service according to the potential clients' requirements.

5.2.2 Location Analysis

As the site plays as well an important role for the success of any product-service system, the location Greater Lisbon was deeply analyzed as a next step. Site-specific decisive criteria for the success of car sharing services were already identified within the framework of the performed *car2go* interview (compare Chapter 4.6). Hence, the knowledge to be gained involved dealing with the following questions:

- How much purchasing power is there?
- How high is the concentration of the target group?
- How is the existing infrastructure?
- Is there an adequate population and population density?
- Are there already existing car sharing providers?

The first market overview was created on the basis of internet research. The majority of the research consisted of gathering statistical data from the database of INE (Instituto Nacional de Estatística), the national statistical institute of Portugal, which is headquartered in Lisbon.

Moreover, the local expansion of charging infrastructure for electric vehicles in Greater Lisbon was investigated via web search, which provided valuable insights.

For the characterization of the car sharing market in Greater Lisbon, additional information could be obtained by contacting *Citydrive*, which is currently the only car sharing provider located within the subregion. The service offerings of *Citydrive* were furthermore tested in order to gain relevant knowledge of the function of car sharing in Greater Lisbon, as well as to identify potentials for service improvement.

5.3 Multi Criteria Sustainability Assessment

On the basis of the findings obtained in the framework of the customer and location analysis a theoretical, locally adapted car sharing concept will be elaborated in the later stages of the dissertation. For the purpose of the evaluation of the model, an assessment tool, consisting of a set of indicators and an assessment matrix will be developed in this section. This tool is used later on to examine if the designed concept might contribute to the *UN 2030 Agenda for Sustainable Development* (UN 2015), which stipulates, among others, to “provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, […] with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons”. As already established in Chapter 3.1.3, trend changes, especially in the light of safe and resilient cities and human settlements are urgently required in many European countries.

The individual criteria, which are predetermined in the following chapters, are later on rated according to a 3-level rating scale as follows: +1 (improvement), 0 (no change), -1 (deterioration). Reference point

for the evaluation of the sustainability is the so-called “zero alternative”, which is in the present case the expected evolution of the environment in Greater Lisbon in absence of the elaborated car sharing concept.

5.3.1 Indicator Selection

Litman (2015b) states in his paper on developing indicators for sustainable and livable transport planning that “indicators are things we measure to evaluate progress toward goals and objectives”. Hence, it is especially important to select indicators, which reflect the overall goal that is sustainable development in the present case. Evaluating the sustainability of transport systems consequently requires a set of indicators that reflects ecological, economic and social goals in an appropriate way. However, it is important that the three spheres of sustainability are considered as a whole, since sustainable development is located at the center of the cross-relationship (compare Chapter 3.1.1). Focusing too much on one category can therefore lead to suboptimal decisions (Litman 2015b). Thus, special emphasis was placed on selecting integrated indicators that have interlinkages with at least one of the two other spheres.

The insights gained in the course of the previous literature review served as a foundation to compile an adequate set of indicators. In particular, the transport related targets of the *EU Sustainable Development Strategy* (compare Chapter 3.1.2) and the *UN 2030 Agenda for Sustainable Development* (compare Chapter 3.1.3) in conjunction with the in Chapter 2.2.2 and 2.2.3 detected negative effects of road transport in Greater Lisbon served as a basis for the development of transport related sustainability indicators. Thus, the theoretically possible contributions of car sharing to sustainable development already identified in Chapter 4.3 can be checked, using the designed concept at the location Greater Lisbon.

Nevertheless, despite the systematic approach, a certain degree of subjectivity is unavoidable in any assessment process, which means there is not one single correct indicator set, since the number of potential indicators is clearly too high and needs to be reduced to few, representative parameters. Therefore, in practice one should invite different kind of stakeholders (e.g. inhabitants, local politicians) as well as experts to establish a more objective and meaningful set, focusing on avoiding redundant indicators. Furthermore, weighing indicators equally, as it is done in the framework of the dissertation, is contrary to the consistent practice of *multi criteria analysis*, but sufficient for a preliminary assessment of the sustainability of the car sharing service to be developed. Accordingly, the tool described hereinafter represents only one, simplified possibility to assess transportation concepts in terms of their contribution to sustainable development.

5.3.2 Ecological Performance

Corresponding to the ecological requirements of sustainable transport systems, the negative influences on the environment have to be reduced. As already identified and discussed in the previous chapters, transport activities nowadays burden man and nature, on both, local and global scale. Engine related gaseous emissions influence the global climate and harm health, building surfaces and the biosphere (Eurostat 2009).

Landscape fragmentation resulting from road building, which is caused by the continuous increasing road traffic, threatens animal and plant species, as elucidated in Chapter 2.2.2. The requirements of the ecological dimension of sustainable transport aim at both, minimizing the inputs (resource and energy consumption) and the mentioned outputs (emissions and land use) of traffic. The European Union tackles these goals in the framework of its *Sustainable Development Strategy* (compare Chapter 3.1.2). Looking at the negative effects of the increasing road traffic in Greater Lisbon identified in Chapter 2.2.2, it gets obvious that many of these aspects are already covered by the SDS.

Table 6. Indicators to assess the ecological performance of mobility concepts

Category		Indicator		Interlinkage
Ecological	Emissions	1	Change in engine related gaseous emissions (e.g. CO, CO_2, PM, NO_X)	
		2	Change in other air-pollutant emissions (e.g. dust, abrasion)	
		3	Change in traffic related noise	
		4	Change in soil pollution (e.g. oil loss)	
	Land Use	5	Change in road congestions	
		6	Change in average public transport occupancy rate	
		7	Change in landscape fragmentation	
		8	Change in soil sealing	
	Resources and Energy	9	Change in energy consumption (construction and operation phase)	
		10	Change in use of renewable energies	
		11	Change in raw material consumption	
		12	Change in amount of waste and disposal	

If the SDS in combination with the identified transport related problems in Greater Lisbon are considered, twelve ecological indicators for the assessment of mobility concepts can be derived, as depicted in the table above. As can be seen from the table, the indicators are divided into three categories: emissions, land use, and resources and energy. The level of interlinkage with the two remaining spheres of sustainable development (economic and social) is presented through a color scale on the right-hand side, whereas purple refers to the economic and blue to the social dimension. The first three indicators

of the emissions category are strongly linked to the social sphere (blue), since gaseous and noise emissions have a major impact on human health and wellbeing. This circumstance generates costs for the public health care system, which justifies the, slightly weaker, interlinkage with the economic sphere (purple). It is important to note that the selection of the level of interlinkage with the two remaining spheres is based on the author's own perception and not based on scientific grounds. The color scale only serves to illustrate the connection between the three dimensions of sustainability.

The remaining interlinkages are not explained in detail, since this would go beyond the scope of the dissertation.

5.3.3 Economic Performance

The economic performance of transportation systems represents as well an important criterion towards sustainable mobility, which can be assessed according to the efficient allocation of financial resources. Hence, sustainable mobility concepts should be tailored to meet specific needs at affordable and fair prices. Table 7 represents the selected economic performance indicators, which are distinguished between provider, customer, and municipality.

Table 7. Indicators to assess the economic performance of mobility concepts

Category		Indicator		Interlinkage
Economic	Provider	13	Change in production costs	
		14	Change in profitability	
		15	Change in customer loyalty	
	Customer	16	Change in operating costs	
		17	Change in investment needs	
		18.	Change in expenses for public transport	
	Municipaliy	19	Change in transport expenditures (e.g. vehicle parking, roads)	
		20	Change in external cost of transport activity (e.g. congestion, accidents)	
		21	Change in subsidies to transport	
		22	Change in economic revenue (e.g. raising city attractiveness, new jobs)	

In order to be sustainable, a car sharing service needs to be financially attractive for the customer on one hand, since affordability is one prerequisite for social acceptance, and thus usage of the product-service system.

On the other hand, the business model should provide a solid base for earnings and prosperity for the provider. These two criteria are essential and must be fulfilled, since a car sharing service would otherwise neither be provided, nor demanded.

Furthermore, the social follow-up costs (external costs) fall into the category of economic performance, which must be as low as possible, since they reduce the population's prosperity. In particular, the expenditures caused by congestions, accidents, and emissions play an important role and should therefore be taken into account.

5.3.4 Social Performance

As the previous investigations revealed, people in the urban area of Greater Lisbon are in particular exposed to traffic related air pollution and noise, which burdens the population's healthiness and wellbeing (compare Chapter 2.2.2). Hence an important aspect that needs to be fulfilled in sustainable transport is to reduce the negative effects of traffic on other parties. This would also have the effect of greatly improving the city attractiveness. Furthermore, transport should not lead to a stronger negative impact on specific groups in comparison with others.

Road accidents constitute an additional life risk residents of metropolitan areas are daily facing. If goal eleven of the *UN 2030 Agenda for Sustainable Development* is recalled, sustainable transport systems should place special emphasis on reducing those urban threats by providing access to safe and accessible mobility, with particularly attention to the needs of disadvantaged people (e.g. disabled or low income). Thus, a mobility concept can only be indicated as socially sustainable, if it allows different social groups to fulfil their mobility needs unrestricted. In this context, a sufficient local coverage of the transport service offered, even in less wealthy residential areas, as well as a change in affordability need to be effected.

Taking into account the previous investigations and insights, the indicators summarized in Table 8 can be derived to assess the social performance of mobility systems.

Table 8. Indicators to assess the social performance of mobility concepts

Category		Indicator		Interlinkage
Social	Healthiness	23	Change in population exposed to traffic noise	
		24	Change in population exposed to air pollution	
		25	Change in risk of road accidents	
	Quality of Life	26	Change in city attractiveness (e.g. lower car traffic)	
		27	Change in access to mobility (e.g. local coverage)	
		28	Change in quality of transport for disadvantaged people	
		29	Change in affordability (household income devoted to transport)	
		30	Change in overall transport system satisfaction	

6 Results

6.1 Customer Analysis

A total of 124 individuals responded to the online survey, whereas students constituted the major part with 48.4 percent. The second largest group of respondents were university researchers with 20.2 percent of the participants, followed by professors (14.5%), faculty workers (10.5%) and non-university individuals (6.5%). Almost all survey respondents (94.3%) were of Portuguese nationality; the remaining 5.7 percent are divided up between German, Spanish, Swiss, Ukrainian, and Brazilian natives. Almost half of the survey participants were residing in the municipality of Lisbon. The second largest share was dedicated to Oeiras with around 11 percent, directly followed by Sintra with 10 percent.

Car ownership and trip purpose

Within the scope of the survey, it could be established that nearly all of the respondents either own a car (56.3%), or have a private vehicle available in the household they are living (32.1%). Hence, cars are not only available in almost 90 percent of the households, they also constitute a frequently chosen transport mean – “regularly use” and “daily use” were the most often chosen answers (62%) regarding the travel frequency. Single person trips (29.5%) and 2-person trips (47.3%) to the university or workplace is thereby the most common reason for travelling by vehicle. Thus, the average daily usage time is relatively low – only 23.3 percent of the respondents reported to use their car longer than 60 minutes per day (compare Figure 15). More than 60 percent of the survey participants use their car only between 0 and 50 minutes on average per day.

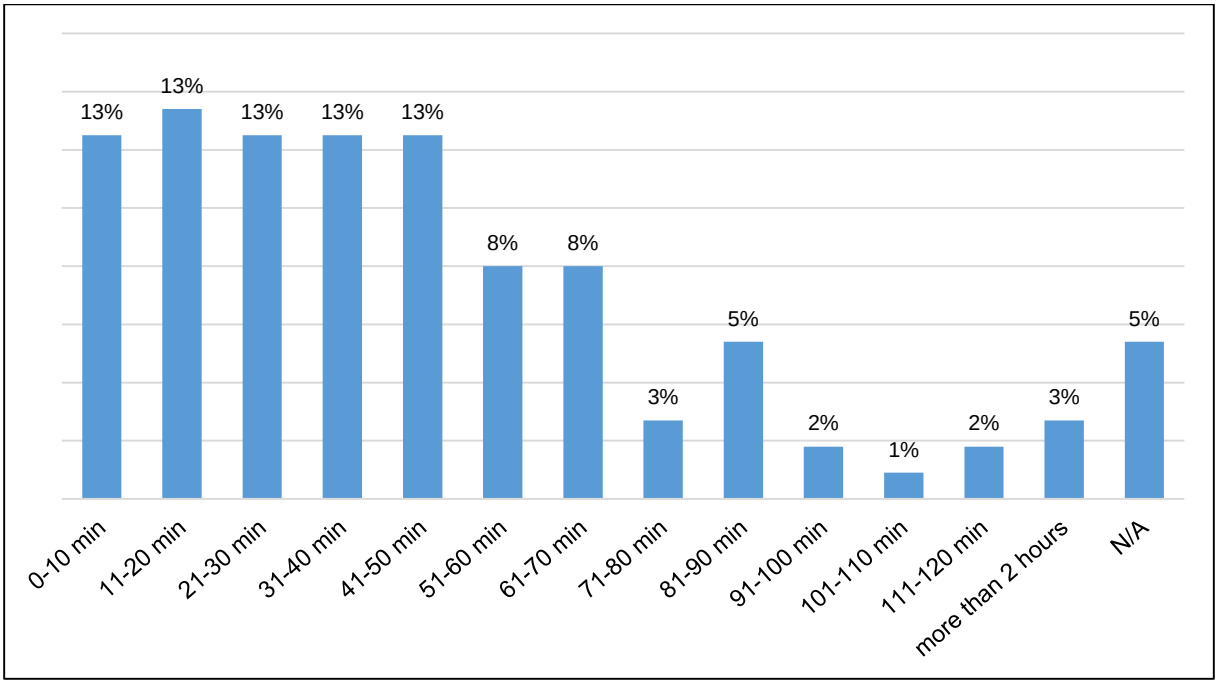

Figure 15. Average daily usage of private household cars

The assumption that automobiles play an important social role by reflecting professional success and prosperity could not be confirmed in the framework of the online survey – they only constitute a very convenient type of transport according to 91.2 percent of the respondents. However, this result might also be attributed to the fact that 48.4 percent of the survey participants were students, which cannot afford expensive cars. Thus, further research would be necessary to sustain this result.

Car sharing awareness

Before being asked questions about the service, the respondents' awareness of car sharing was checked firstly. Thereby it established that this kind of product-service system is not yet well-known in Greater Lisbon. Almost 50 percent confused car sharing with ride sharing. In their understanding, car sharing refers to a service that brings together potential fellow passengers and people who have free available seats in their cars. Further 19.6 percent of the survey participants did not have a conception or idea, what is understood by the term "car sharing". This is especially of interest, when it is taken into consideration that there is already a car sharing operator in Lisbon, which is analyzed in a later chapter.

Attitude towards car sharing

After these significant results were obtained, all respondents were provided with information. In particular, the survey participants were asked to read a brief explanation of car sharing. Subsequently, they were asked whether they could imagine to use such a service. The overall conclusion can be evaluated positively – 59.4 percent answered that they would use a car sharing service, 32.7 percent were interested, but remained skeptical. Only a small proportion of 7.9 percent of the survey participants showed a "negative" attitude to the service and reported that they could not imagine to use car sharing in Greater Lisbon. Reasons for this choice were, among others, a lacking driving license or car ownership.

Expected service usage

The next step was to analyze the preferred service usage, which means the participants were asked what they would typically use car sharing for. For this purpose, the respondents could choose between six distinctive types of trips represented in Figure 16. Furthermore, the potential frequency of occurrence of those trips was weighted differently. The options offered were "never", "slightly", "regularly", and "daily", whereas "daily" was given the highest weighting (3) and "never" the lowest (0). The weighted average was calculated afterwards, which has led to the outcomes depicted in Figure 16. As can be seen from the figure, trips to the university or workplace constitute the type of trips a car sharing service in Greater Lisbon would most often be used for, according to the respondents. Only few survey participants have chosen the option holiday trips, which is also usually not intended by local car sharing services, as the service area is limited.

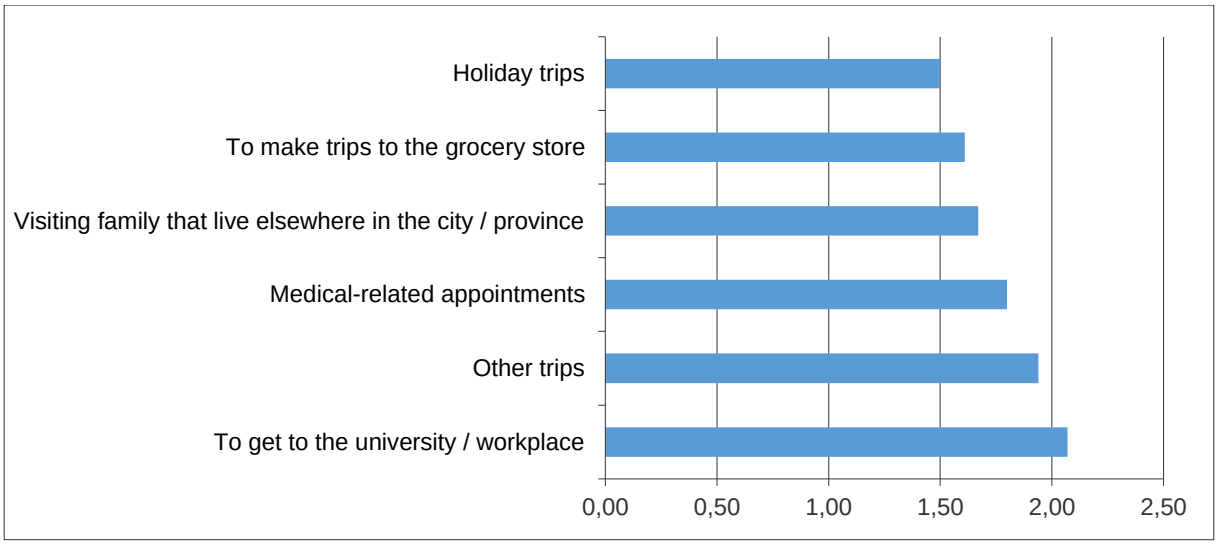

Figure 16. Expected car sharing usage

Expected monthly expenses

Having established that most of the survey participants are attracted to car sharing, they were subsequently asked, how much money they would anticipate spending on such a product-service system within a single month period. As one can see from Figure 17, 47 percent have chosen less than 25 Euro per month, which reflects a relatively low value. According to a survey of car sharing members conducted by Millard-Ball et al. (2005) in North America, respondents reported to pay, on average, $60 per month for the service.

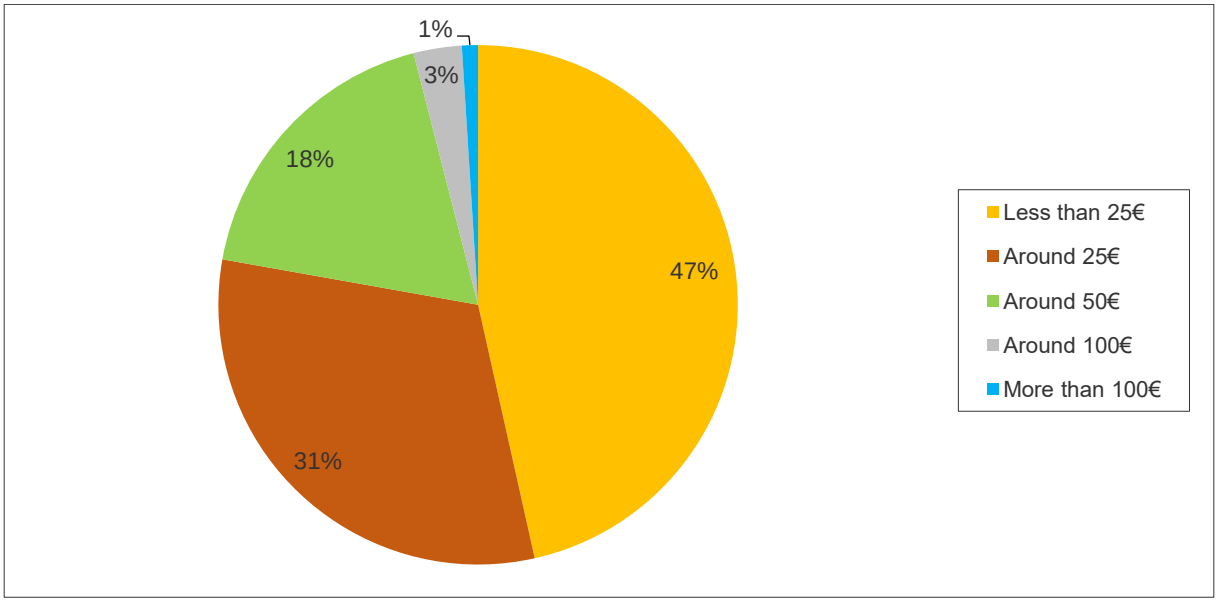

Figure 17. Potential monthly car sharing budget

Motivations for joining car sharing

As a next step, the respondents were given the opportunity to choose between, as well as to identify, motivating factors for joining and using car sharing. According to the survey participants, car sharing appeals to them for the following reasons:

- It could reduce the travel related emissions and air pollution 60%
- It could reduce inner-city traffic jams 41%
- It could help to avoid replacing an old vehicle 38%
- It could help saving money on transportation 29%
- It could eliminate the stresses of owning a car 13%

Multiple responses were permitted; thus these percentages add up to more than 100%. Environmental factors are the primary attraction to join a car sharing service, according to the survey results. Some of the more interesting “other reasons”, cited in 10% of the responses, included:

- “Especially the combination of getting rid of the responsibilities of having a car and not needing to be depending on the public transport (in terms of time, strikes, access, etc.).”
- “I think it's useful for people who don't own a car, but for the average family with children it’s not feasible.”
- “It may be a more convenient mean of transportation than public transport to access certain areas of the city.”
- “It’s another way to change mentalities, build a better world less selfish and much more cooperative.”

Expected behavioral change

Subsequently, the respondents were asked if a car sharing membership, instead of vehicle ownership, would change their travel behavior. In particular, they were asked if car sharing would encourage them to increase the use of more sustainable transport modes, such as public transport, walking and cycling. Approximately half of the survey participants (49%) cited that they would most likely change their travel behavior. 27.6 percent responded that a car sharing membership would not push their travel behavior towards sustainability. The remaining 23.4 percent has chosen N/A (not applicable), which means they would not use car sharing at all.

Least attractive features of car sharing

Afterwards, the survey participants were asked about features that seem most unattractive in joining a car sharing service. The least attractive feature of car sharing service in Greater Lisbon is considered to be the availability of vehicles (compare Table 9) in specific areas or at specific times during the day.

Some very precise doubts included:

- “I want a car and there is no one available in the area, or empty for my use, which may delay my plans.”
- “Availability of cars around my house and place of work. I live in Mafra and work in Lisbon, what I think would be a problem for using a car sharing service.”
- “Not having a vehicle available anytime I want, or in case of emergency.”

The second largest concern (29.3%) refers to the distance or effort to get to a car sharing vehicle and, to a lesser extent, the price of the service (27.6%). Less respondents have cited that the cleanliness of vehicles could be a critical issue as well as the loss of independence.

Table 9. Least attractive features of car sharing

Feature	% citing this feature*
Vehicles not available	46.6%
Distance / effort to get to the vehicle	29.3%
Price is too high	27.6%
Vehicles not always clean	8.6%
Loss of independence	5.2%

* Multiple answers permitted; thus, percentages add up to more than 100%.

User requested features and future vision

Finally, survey participants could express their wishes and expectations of a car sharing service in Greater Lisbon, as well as their future vision of mobility services. As expected, the most frequently given answer regarding the service features was the availability of vehicles. In particular, survey participants who can imagine to use car sharing wish to have an adequate number of cars evenly distributed within the operation zone. Furthermore, cars should be in good condition, which means well maintained, clean, and without damage. Several respondents cited that they would prefer electric vehicles and free access to parking zones within the city.

Some interesting comments about the future vision of mobility were:

- “Autonomous vehicles […] that will pick you up and drop you wherever you want (like a taxi without a driver).”
- “A more efficient public transport network, with a higher degree of access to it.”
- “We should invest a lot in electric vehicles and bikes.”
- “For people residing and working in Lisbon, more cycle paths and sidewalks.”

Especially the idea of a car sharing service based on autonomous electric vehicles that pick one up at home was frequently mentioned by the participants and seems reasonable in the near future.

6.2 Location Analysis

6.2.1 Local Conditions

Population density

As a first step of the location analysis, the average population density of Portugal and its greatest urban areas were investigated, since an adequate density is prerequisite for launching a car sharing service (compare Chapter 4.6). According to Figure 18, Portugal's population density accounted 113 inhabitants per square kilometer in 2011, which was slightly below the European average. In this context, Greater Lisbon and Greater Porto represented the two urban agglomerations with the highest population densities throughout Portugal. The population density of Greater Lisbon was the second highest and accounted 1,458 residents per square kilometer in 2011. Greater Porto was slightly more densely populated with 1,552 residents per km^2.

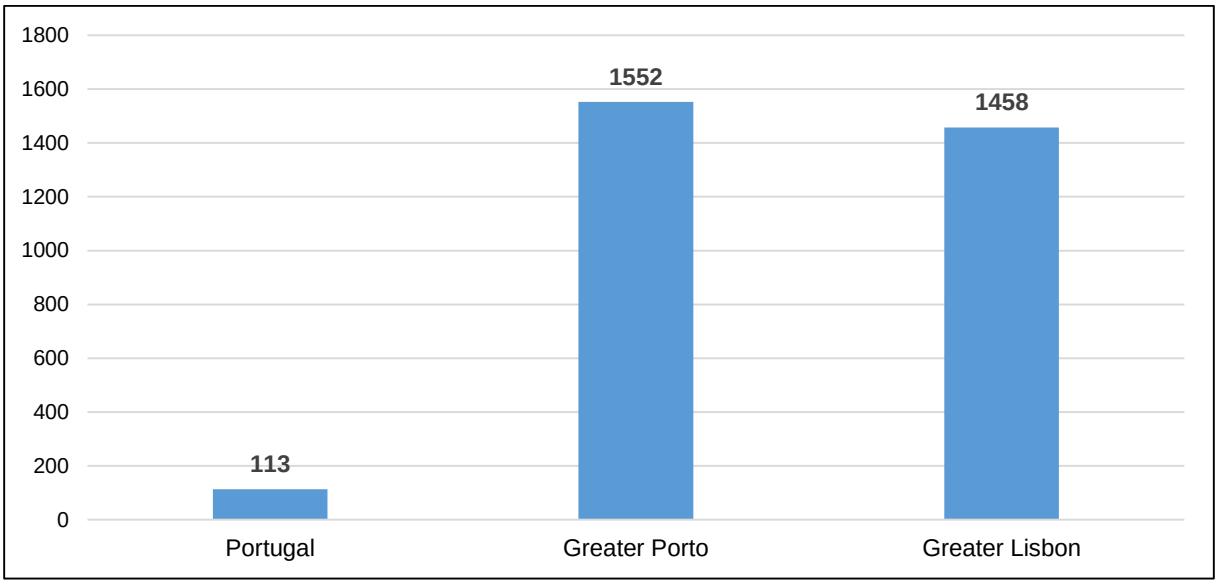

Figure 18. Population density (No./km^2) by place of residents in 2011 (INE 2015)

Remarkable is the fact that the population density of Lisbon was with 6,325 residents per square kilometer 4.3 times as high as the Greater Lisbon average in 2011 (INE 2013). This value represents a very high density that was even significantly higher than the density in London region in 2011, which amounted 5,199 (ONS 2012). Hence, it can be assumed that the population density is adequate to launch a car sharing service. However, it should be highlighted that a regionally adapted car sharing concept has to respect the strong density variations within the area of Greater Lisbon in order to be efficient.

Purchasing power

Secondly, the purchasing power was investigated, which is an essential element to assess the demand and the specific market conditions before launching tailored services. It can be defined as the nominal net disposable income of the population, including government transfers, like pensions or unemployment benefits (Die Welt 2015). In national comparison, Greater Lisbon represents the urban agglomeration with the highest percentage of purchasing power throughout Portugal. In particular, around 28 percent of the country's total purchasing power were concentrated at this location in 2011, as can be seen from the figure below. Greater Porto, the second largest urban agglomeration in Portugal, ranked second with only half of the purchasing power of Greater Lisbon (14 %).

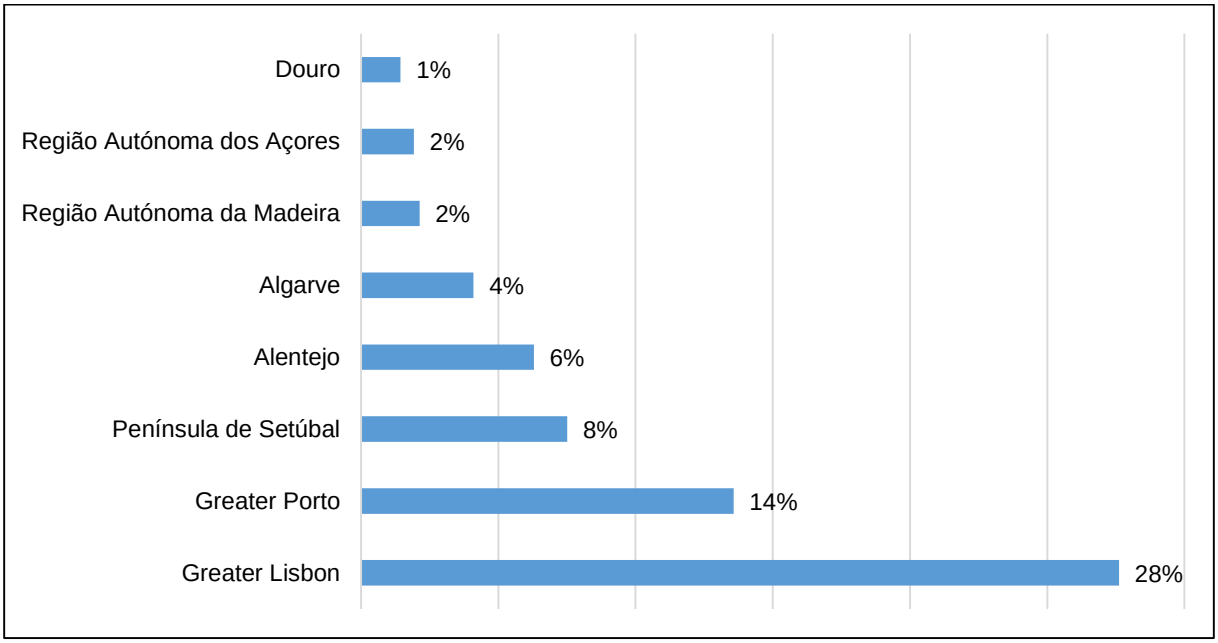

Figure 19. Proportion of purchasing power by geographic localization in 2011 (INE 2015)

Also in 2011 the purchasing power of Greater Lisbon was much higher than the European average and at similar level to other large cities in Europe (Lichtner 2011). Consequently, from an economic point of view, Greater Lisbon represents the most attractive region in Portugal for launching a car sharing service.

Age structure

The subsequently following analysis of the age structure served to determine, if the car sharing target group is sufficiently represented in Greater Lisbon. In the early days of car sharing, more than the half of the sharers were principally found in the age group 30 to 40. In particular, almost 90 percent were aged between 25 and 45 years. At the turn of the millennium, the target group was still situated in the same age category, but the acceptance of shared use increased significantly (mobilaro 2016).

A new attractive target group, which car sharing providers recently discovered, are students, since they require mobility on one hand, but often can neither afford a private vehicle, nor the corresponding maintenance costs on the other hand (mobilaro 2016).

If the age structure of Greater Lisbon is taken into account, as it is presented in Figure 20, it becomes obvious that the car sharing target group (25-44 years) represents the largest share of the total population with 30 percent.

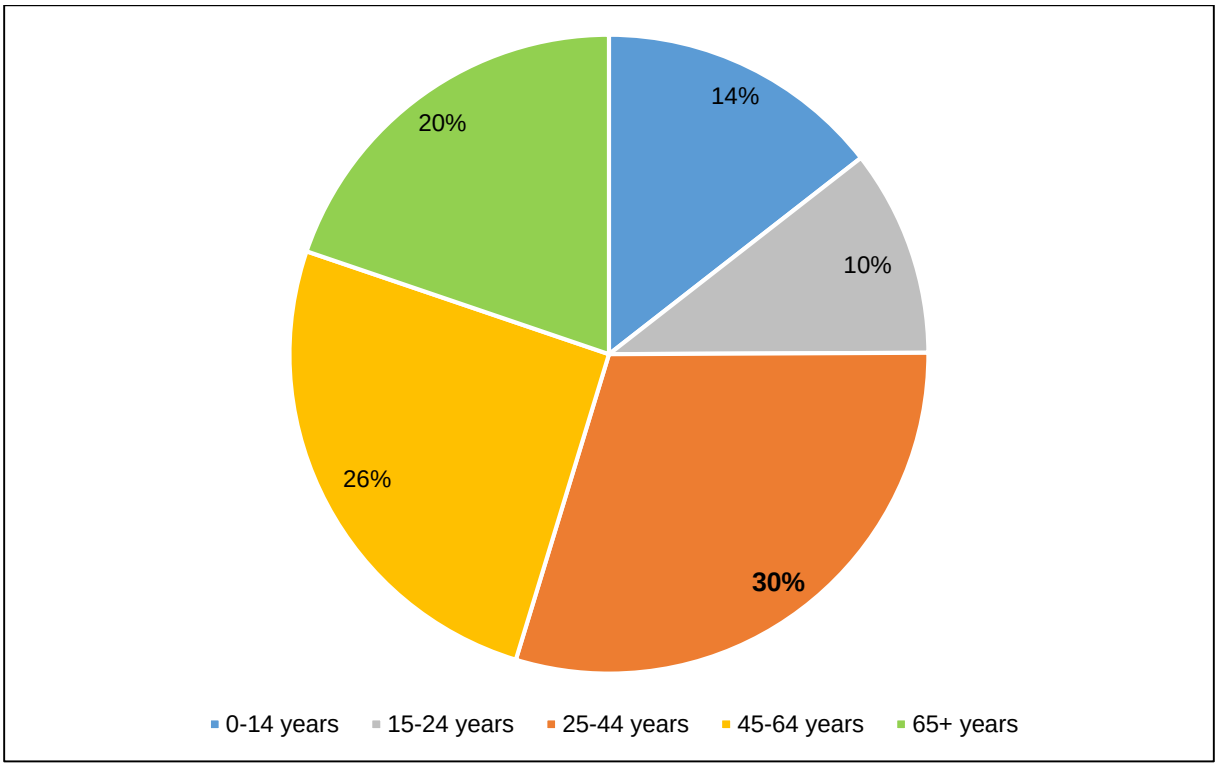

Figure 20. Age structure of Greater Lisbon in 2011 (INE 2015)

Moreover, Greater Lisbon represents the Portuguese subregion with the largest number of students, due to its high university density. Students enrolled in higher education in the academic year 2014/2015 accounted 119,340 in Greater Lisbon, 43 percent more than in Greater Porto in the same year (INE 2015). Hence, it can be concluded that the car sharing target group is sufficiently represented in Greater Lisbon.

6.2.2 Charging Infrastructure

In order to verify if a car sharing solution based on electric vehicles would be feasible in Greater Lisbon, the expansion of the local charging network has first to be investigated. Under the directive 2009/28/EC of the European Parliament, Portugal has committed itself to raise the share of energy from renewable sources in gross final consumption to 31 percent by 2020 (European Union 2009). In the framework of a national energy strategy, Portugal has also set the objective of having 10 percent of the traffic energy consumption coming from renewable energies by 2020. In the foreground is hereby the expansion of wind power with the potential to cut the carbon dioxide emissions from transport. For those reasons, Portugal started a nationwide electro-mobility initiative in 2008 with the creation of the MOBI.E program. At present, MOBI.E is an integrated and interoperable network of about 1,000 charging points (normal and fast charging), which are distributed throughout Portugal (MOBI.Europe 2012).

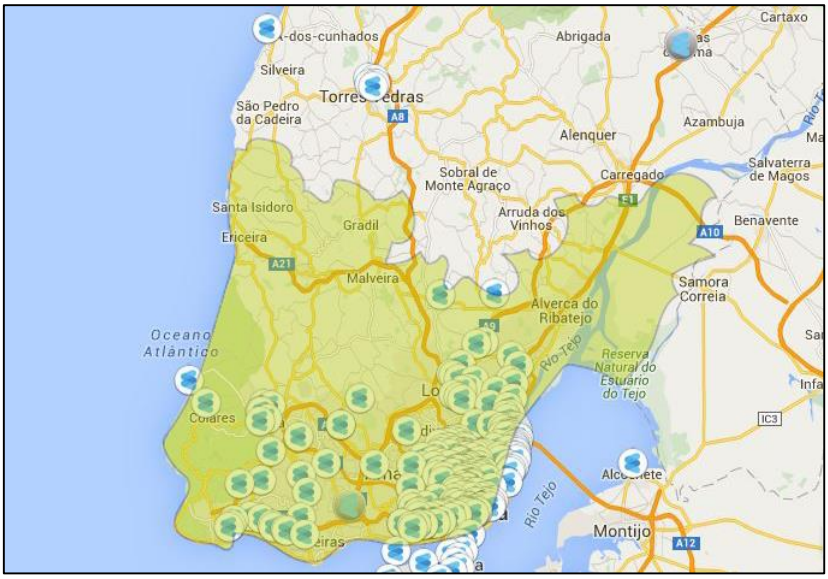

Figure 21. Charging network in Greater Lisbon (MOBI.Europe 2016)

As outlined in Figure 21 above, the density of MOBI.E charging points is very high but unevenly distributed in the Greater Lisbon subregion (green marked zone on the map). Due to the large population, the density of charging stations is highest in the municipality of Lisbon. Further charging points are primarily located along the south coast from Oeiras to Cascais, as well as in Sintra. Nonetheless, it can be noted that the charging infrastructure is very well developed. According to MOBI.Europe (2012), the interoperable network architecture is even designed to add services like mobile apps or car sharing services on top. The focus is on individual clients as well as vehicle manufacturers, energy retailers and private operators.

On the basis of observations and personal experience it is noticeable, however, that the actual use of the charging network is very limited in Lisbon. Only in rare situations, electric vehicles can be seen connected to the charging points. Furthermore, it is conspicuous that some of the charging points are in poor condition and inoperable, which is probably attributed to the low utilization.

6.2.3 Car Sharing Market

Currently, there is only one car sharing provider operating in Lisbon, which was launched in 2013 under the name *Citydrive*. *Citydrive* is a pilot project initiated under the umbrella of *Mobiag*, a Portuguese start-up. *Mobiag* aims at connecting different car sharing operators in the future, thereby enabling the users to access cars of different operators in different cities, using only one platform. *Citydrive* is organized according to a free-floating principle, as it was previously elucidated in Chapter 4.1. Hence, users can spontaneously access parked vehicles in Lisbon, after they have passed through the following 3-step pre-registration process:

1. Signing-up and email address confirmation
2. Scanning and uploading of ID and driving license
3. Entering billing address and fiscal number

Additionally, if the service is used for the first time, an amount of 20 EUR must be deposited in the customer's account, which is used for the first service payments. Service costs amount 0.29 EUR/min if a car is driven, with a maximum of 9.90 euros per hour. Parking, fuel and maintenance costs are included in this value. Interim parking (ongoing rent) leads to reduced costs of 0.10 EUR/min – the first 15 minutes are free of charge (Citydrive 2016). *Citydrive's* operating range is limited to two zones, green and yellow, as illustrated in Figure 22.

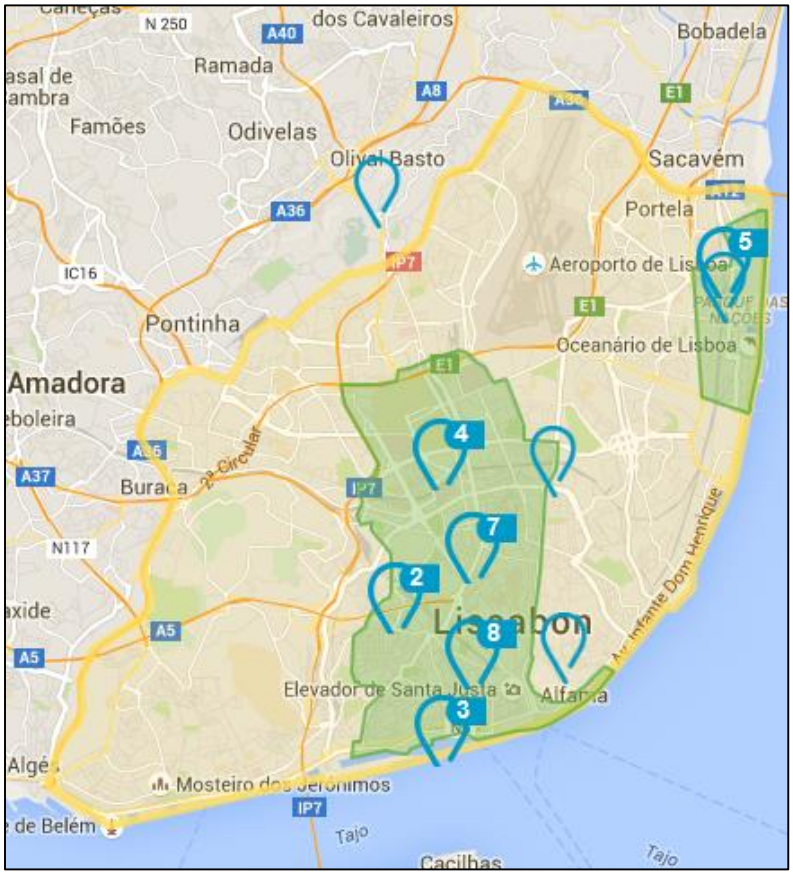

Figure 22. Service area of *Citydrive* in Lisbon (Citydrive 2016)

If vehicles are left after rental within the green zone, no additional costs occur. Otherwise, in case the vehicle is parked in the yellow zone, a fee of 10 Euro applies if the car is not used in the following 12 hours. Cars can only be driven within Portugal`s national borders. However, *Citydrive* is mainly intended to travel within the city and public transport is seen as a complement, according to Portuguese Entrepreneurs (2014). Overall, there are currently three different types and a total number of 40 vehicles provided by the *Citydrive* car sharing service, all equipped with conventional combustion engines. This figure represents a very small value compared to the city's population and corresponds to 0.04 vehicles per 1,000 inhabitants. However, it is planned to expand the service area, as well as to increase the number of cars to 60 in the near future.

The exact composition of the vehicle fleet, including the specific CO_2 emissions per vehicle type, is given in Table 10. This information, however, is not provided on *Citydrive's* webpage and could only be obtained by direct inquiry.

Table 10. Composition of *Citydrive's* car sharing fleet (Coelho 2016)

	Opel Adam	**Skoda Fabia**		**VW up!**
Motor Data	Gasoline (51 KW)	Gasoline (55 KW)	Diesel (66 KW)	Gasoline (44 KW)
Number	20	5	5	10
g CO_2/km	115	108	88	105

Calculating the weighted average of the fleet's CO_2 emissions results in a value of 108.25 g CO_2/km. To put this value in relation, a benchmarking with two international operating car sharing providers, *DriveNow* and *car2go*, was conducted. For this purpose, the corresponding CO_2 emission averages were calculated based on the respective vehicle fleets.

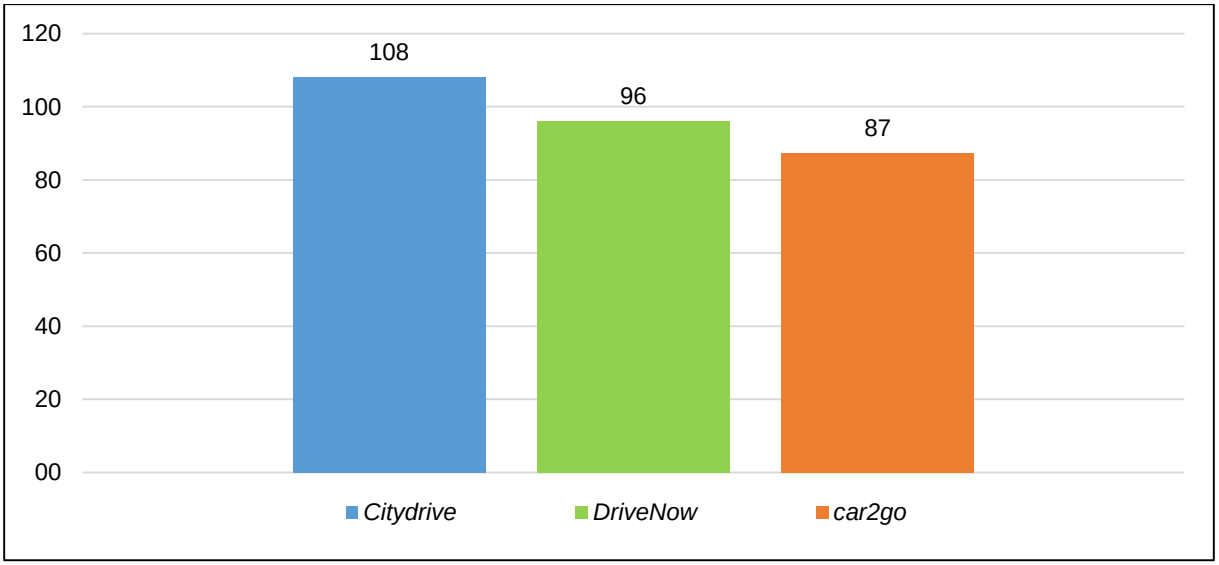

Figure 23. Car sharing average CO_2 emissions benchmark in g CO_2/km

The results represented in Figure 23 demonstrate that *Citydrive's* average carbon dioxide emissions are clearly above the one of *car2go* and even *DriveNow's* emissions are distinctively lower with 96 g CO_2/km. This strong deviation results from the amount of electric vehicles within the fleets of *car2go* and *DriveNow*, which has a positive effect on the emission weighted average. As mentioned before, *Citydrive* is currently only offering vehicles with conventional combustion engines.

To gain greater insights into how *Citydrive* performs in everyday life in Lisbon, the service was tested by the author. It turned out that the pre-registration process is not yet fully developed and difficult to handle, especially for foreign people. Users who want to complete the online registration process are obliged to enter the Portuguese fiscal number (NIF). The result is that tourists and other temporary residents, like Erasmus students, are unable to use the service, since they usually do not possess a NIF. After successful pre-registration, the access to the vehicles is possible by smartphone with permanent access to the internet or via smartcard. However, the necessary application could only be installed on an Apple device, Android is apparently not supported yet. This is probably due to the fact that the service is still not entirely developed. If it stays the way it is though, the target group will be severely restricted. Nonetheless, the application itself functions very well. It provides the user with information about the nearest available vehicle including walking distance, type of vehicle, fuel level as well as the prices per minute.

To start the rent, the next step is to book the vehicle by smartphone or computer with internet access, which reserves the car for a duration of 15 minutes. If the customer opens the car using his smartphone, he has to check the vehicle for damages before he can start the engine. In case of obvious damage, the application is used to report directly to *Citydrive*. The dash key necessary to start the engine is located in the vehicle interior at a fixed position. At the end of a trip, the key is put at the same position. After the vehicle rental, cars can be left in freely accessible, fee-based locations, since there is a contractual agreement between *Citydrive* and the entity that manages the on-street parking in Lisbon.

6.3 Opportunities for Greater Lisbon

The previously conducted customer and location analysis have revealed that Greater Lisbon would overall be a good place to launch a car sharing service. Despite the fact that respondents often did not understand what car sharing is and how it differs from ridesharing, they were open to, as well as interested in new mobility concepts, as the online survey has shown. Nonetheless, the relatively low number of survey participants is obviously not population representative, which means that further research would be required to reach definite conclusions about the social acceptance of shared car usage in the region.

Another fact that became clear was that people do not have a true understanding of the costs of car ownership. When the survey participants were asked, how much money they would anticipate spending in a single month period for a car sharing service, they tend to choose the lowest value (less than 25€). This could be based on the fact that people often solely consider the variable expenses, such as fuel, when comparing the costs with another transportation mode (Millard-Ball et al. 2005). However, particularly for drivers with low annual mileages, as most of the survey participants, car sharing can be worthwhile financially, as already mentioned in Chapter 4.3.2 and further investigated in the later stages.

The site criteria speak clearly in favor of launching a car sharing service. The following reasons summarize the location specific advantages:

- High population density, especially in Lisbon with 6,325 residents/km^2
- Region with the highest percentage of purchasing power in Portugal
- High concentration of the car sharing target group
- Highly developed electric charging infrastructure
- High market potential and low competition

Car sharing offers the best potential in urban neighborhoods with such criteria. Especially a high population density combined with scarce parking, as it is given in the municipality of Lisbon, makes car ownership less convenient and car sharing more attractive (Millard-Ball et al. 2005). “If residents have to walk a block or two to their car, they may as well walk the same distance to a car sharing location”, according to Millard-Ball et al. (2005).

In the following sections, a theoretical car sharing concept will be developed based on the insights gained through the previous research and the conducted online survey. The major effort is put into the creation of a sustainable product-service system, which could contribute to reduce the identified traffic related problems in the Greater Lisbon region.

7 Concept Development

7.1 Vehicle Strategy

As a first step of the concept development, an adequate car sharing vehicle has to be chosen. For this purpose, the vehicle fleets of existing car sharing operators are analyzed at the forefront, to compare the vehicle strategies of the different companies. In particular, the fleets of the car sharing providers *car2go*, *DriveNow* and *Citydrive* are explored respectively. Subsequently, one vehicle from every fleet is chosen, which is considered to suit the local requirements of Greater Lisbon as well as the superordinate goal of sustainable development best. Afterwards the so-called “weighted objectives method” is used to make a decision between the previously selected alternatives.

If the vehicle fleets of the three operators are compared, differing strategies can be identified. *Car2go* currently pursues the strategy of low fleet variation by offering only one vehicle type, the *smart fortwo*. The small car offers sufficient space for two passengers, as well as little luggage. According to smart (2016), it is designed for dense urban areas and its special feature is the perpendicularly parking (instead of parallel), possible due to its short wheelbase. *Car2go* presently offers the *smart* with two different drive configurations – either with conventional combustion engine, or as electric vehicle (*smart fortwo electric drive*). *Car2go’s* strategy of low variation offers several advantages on one hand. Customers immediately know how the car works and service and maintenance is more cost efficient and easy to handle (compare Annex 3). But on the other hand, seats and space are limited, which clearly restricts the target group. Families are simply not able to use c*ar2go’s* service, since only two seats are available. Whether or not electric vehicles are used, depends on the development of the local charging infrastructure, as became clear in the framework of the phone interview conducted with *Car2go* (compare Annex 3). Thus, in cities with well-developed infrastructure the car sharing fleet only consists of electric vehicles. Since Greater Lisbon clearly fulfils this criterion, as identified in the location analysis (compare Chapter 6.2.2), the *smart fortwo electric drive* (*ed*) is taken into consideration as a potential car sharing vehicle for the service concept.

DriveNow pursues a different strategy with a higher fleet variation, comprising eleven vehicle types (BMW and MINI) either with combustion engine or electric engine. Since Greater Lisbon offers a very well developed charging infrastructure, also here only the electric vehicle will be taken into consideration for the concept development, which is in this case the *BMW i3*. According to BMW (2016), the *i3* is “designed for sustainability at every stage, from the development of the car to its production and everyday use”. The energy for the production of the vehicles is generated from renewable sources, like wind turbines, and the interior is partially manufactured from biodegradable materials like wood, wool or leather (BMW 2016). In contrast to the *smart*, the *BMW i3* offers space for four passengers, which gives economic advantages on one hand, since the target group is clearly enlarged. On the other hand,

handling and parking in inner-city areas constitutes a bigger challenge, which is of particularly interested if the high population density of Lisbon is taken into consideration.

Citydrive, the Portuguese car sharing company, currently offers three different vehicle types, as depicted and analyzed in Table 10. As already mentioned before, all three cars, *Opel Adam*, *Skoda Fabia* and *VW up!*, are only available with conventional combustion engine – electric vehicles are currently not offered by *Citydrive*. Since the primary goal of the concept to be developed is to reduce the traffic related problems in Lisbon, the model with petrol engine and the lowest g CO_2/km is selected, which is in this case the *VW up!* with 105 g CO_2/km. Although the *Skoda Fabia* with diesel engine has slightly lower carbon dioxide emissions, it is not considered due to the higher emission of harmful particulate matters, characteristic for diesel engines. Furthermore, the *VW up!* is slightly more agile due to a shorter wheelbase, which facilitates parking and shunting in dense urban areas like Lisbon. As the *BMW i3*, it offers space for four passengers.

After the three vehicles were chosen, the weighted objectives method can be applied, to choose between the alternatives. As a first step of the method, criteria have to be selected according to which the selection will be made (van Boeijen et al. 2013). Six criteria were chosen for the decision making, which were weighted according to the impact on the effects of the increasing road traffic (compare Chapter 2.2.2 and 2.2.3). It is important to note that the weighting of the individual criteria is based on the author's own perception, however in practice it should be done in cooperation with experts / stakeholders, using a structured technique (e.g. Delphi method, expert judgement). The criteria are listed and described below:

- **Engine**
  The highest weighted criterion reflects the energy efficiency / exhaust emission category of the vehicle, since the vehicle's engine has a major impact on three effects identified in the problem analysis (air / noise pollution and GHG emissions). Thus, cars with electric engines are highest scored, since they completely avoid air-pollutant and noise emissions in the city.
- **Size**
  The second criterion reflects the vehicle size. Smaller vehicles achieve a higher score, since they are easier to handle in ancient urban areas like Lisbon and reduce the static and dynamic land use, which was identified as a major effect of the increasing road traffic during the problem analysis.
- **Material use**
  The third criterion deals with the material use. Factors that play a role are the quantity of material that is used to construct the vehicle, as well as the type of material (e.g. biodegradable).

- **Cost**

  The fourth criterion reflects the economic site, in this case the acquisition costs of a vehicle, which are reflected in cost/minute of the service. Costs do not have a direct impact on the effects of the increasing road traffic, but an indirect. If the service costs are affordable, people intend to make more use of the service (e.g. students), which reduces the negative impacts of road traffic.
- **Handling**

  The fifth criterion, the handling, indicates the suitability for daily use. Cars with combustion engine are advantaged, since the time consuming battery recharging process is not an issue.
- **Flexibility**

  The lowest weighted criterion is the flexibility. Factors that play a role here are for instance the range and the number of seats. Since car sharing services are intended to travel within the city, the criterion has only little influence.

The next step of the weighted objectives method is to attribute values to how each vehicle meets the criteria (van Boeijen et al. 2013). For this purpose, the scores were ranked according to a range from one to ten based on a web research of the technical specifications of each vehicle. Finally, the total score of each car was calculated by summing up the scores, considering the weight of each criterion.

Table 11. Car selection based on weighted objectives method

		smart fortwo ed		***BMW i3***		***VW up!***	
	Weight	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**
Engine	40	9	360	10	400	5	200
Size	20	9	180	6	120	6	120
Material use	15	6	90	7	105	5	60
Cost	10	5	50	4	40	8	80
Handling	10	6	60	5	50	8	70
Flexibility	5	3	15	5	25	7	35
Total score	100		755		740		565

As can be seen from the table above, the *smart fortwo ed* achieved with 755 points the highest total score and represents therefore the most efficient alternative. This choice is also in accordance with the White Paper “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system” of the European Commission (2011), which recommends the use of “smaller, lighter and more specialized road passenger vehicles”. The *smart fortwo electric drive* constitutes a vehicle, which most likely meets those requirements. With a wheelbase of only 1,867 millimeters (smart 2016) it is tailored to the local requirements of Lisbon, like the narrow streets and scarce parking spaces.

Furthermore, single person trips (29.5%) and 2-person trips (47.3%) to the university or workplace were the most common reason for travelling by vehicle in Greater Lisbon, as the only survey revealed. Thus, in approximately 80 percent of the cases a car with two seats would be sufficient, which is also affirmed through observations in daily life in Greater Lisbon. The *smart fortwo electric drive* offers a range of 145 kilometers, which would as well meet the requirements of the survey participants – more than 60 percent of the respondents cited to use their car only between 0 and 50 minutes on average per day. Another advantage is the drive: due to its electric engine, the *smart fortwo electric drive* produces zero emissions in the city. Furthermore, as already identified in Chapter 4.6, a low fleet variation leads to consistency, and thus customers know how the car works. Additionally, service and maintenance is more cost efficient and easy to handle

7.2 Business Area Determination

Subsequently, the business area of the car sharing concept has to be determined, which has a significant impact on the prospective corporate success. Several studies have already identified neighborhood characteristics, where car sharing is most likely to succeed, which have already been partly mentioned in the sections before. According to Millard-Ball et al. (2005), these characteristics include:

- **Parking pressure**
  To own a car is less convenient in areas with a lack of parking spaces, making car sharing an attractive option.
- **Ability to live without a car**
  Car sharing is not an option that meets the entire mobility needs of a household. The connection to a good public transportation network is therefore a key factor.
- **High density**
  A high population density means there is a large customer group within walking distance of a car sharing vehicle (doubling the density will double the number of potential customers).
- **Mix of uses**
  Business members have an important impact on the success of a car sharing service, since they use the cars during the workday. In contrast, private users tend to use the vehicles in the evenings and at the weekend.

Obviously, these characteristics are highly correlated. A lack of parking for instance, often occurs in dense areas with mixed-use neighborhoods and good public transportation and public transportation tends to be well developed in high density districts. Keeping these four success factors in mind, the nine municipalities of Greater Lisbon can be analyzed accordingly. The business area selection was thus mainly based on the population density indicator. Additionally, the availability of high-frequency and high-speed public transportation was taken into consideration, which is realized by the subway in the case of Greater Lisbon.

As already mentioned in Chapter 2, Amadora and Odivelas are the two municipalities with the highest population density in Greater Lisbon (compare Table 12), which leads to a large customer group representation. Additionally, both districts are directly connected to the subway network, which clearly speaks for offering a car sharing service in those areas, as the public transport system can compensate restricted car usage. Lisbon takes the third place regarding the population density and is naturally the municipality with the largest population of 547,733 inhabitants and the best public transport infrastructure. Offering the car sharing service in these three areas thus seems reasonable and economically sensible.

In addition to Lisbon, Amadora and Odivelas, the Taguspark located in the region of Oeiras will be integrated into the operating area of the car sharing service. The science and technology park offers a large customer group, due to the large concentration of national and international enterprises. Furthermore, one campus of the school of engineering IST (Instituto Superior Técnico) is located there, which leads to a high level of commuter traffic from Lisbon in the morning and in the afternoon. The survey results underpin the decision to include the Taguspark into the service area, since trips to the university or workplace constitute the type of trips a car sharing service in Greater Lisbon would most likely be used for (compare Figure 16). Taguspark's mission, to "promote a sustainable urban environment" (Taguspark 2016), agrees furthermore perfectly with the car sharing concept to be developed and such a mobility concept would further raise the attractiveness and competitiveness of the technology park. Additionally, the good accessibility guarantees fluid traffic to Lisbon downtown within 20 minutes (Taguspark 2016). A conceptual map of the determined rental zone may be consulted in Annex 12.

Table 12. Population density (No./km^2), population (No.) and area (km^2) by place of residence (INE 2014)

	Population density (No./km^2)	**Population** (No.)	**Area** (km^2)	**Subway connection**
Amadora	7,397.7	175,136	23.7	Yes
Odivelas	5,758.1	144,549	25.1	Yes
Lisbon	5,090.4	547,733	107.6	Yes
Oeiras	3,769.6	172,120	45.7	No
Cascais	2,149.6	206,479	96.1	No
Loures	1,224.0	205,054	167.5	No
Sintra	1,193.3	377,835	316.6	No
Vila Franca de Xira	439.7	136,886	311.3	No
Mafra	278.4	76,685	275.4	No

In the following, the average population density of the determined service area is calculated (without Taguspark):

$$Avg.pop.dens._{Business\ area} = \frac{175{,}136 + 144{,}549 + 547{,}733}{23.7 + 25.1 + 107.6} = 5{,}546.2\ No./km^2$$

Since it was previously determined that the population density of Lisbon is significantly higher than the one of Greater Lisbon, it should be checked once more, if the density of the service area is sufficient. Therefore, the figure was compared with the population densities of European cities, where there are already existing car sharing services. The results of this benchmark, depicted in Figure 24, demonstrate that the population density of the determined area should be adequate for offering a car sharing service. Only Milan, one business location of *car2go*, offers a significant higher population density than the concept area with 7,395 inhabitants per square kilometer. Madrid, Berlin and Amsterdam offer lower population densities. However, it has to be said that basis for the benchmarking of the population densities was the entire urban area of the four cities Milan, Madrid and Amsterdam, which does not completely reflect the reality, since car sharing operators often restrict their operating area within cities.

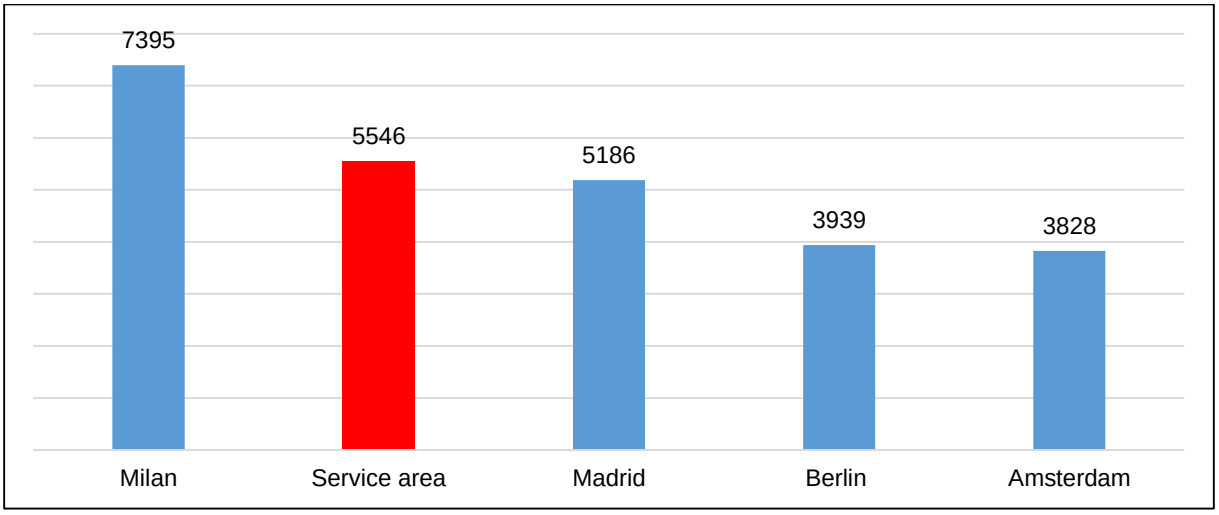

Figure 24. Car sharing areas population density (No./km^2) benchmarking

7.3 Service Details

After the car sharing vehicle strategy as well as the specific operating area within the Greater Lisbon subregion were determined at the forefront of Chapter 7, the detailed service strategy has to be elaborated in the following sections.

7.3.1 Car Sharing Strategy

As already established in Chapter 4.1 of the present dissertation, there are mainly two types of car sharing services offered by enterprises – station-based and free-floating car sharing. Customers using a station-based car sharing service pick up a car from fixed service stations and return it to another, whereas a free-floating service allows the users accessing vehicles spontaneously within the operating range. Hence, both service strategies differ considerably and offer their own individual advantages. For instance, logistics tend to be less challenging to manage for station-based car sharing concepts, as Le Vine et al. (2014) mentioned in their scientific report “Carsharing: Evolution, Challenges and Opportunities”. In addition, station-based car sharing also gives the option to integrate further customer services, such as charging points for electric vehicles or kiosks (Le Vine et al. 2014). Thus, it can be concluded that the operational costs tend to be lower, since the organizational effort can be mitigated. However, there is a not negligible trade-off between cost savings and customer satisfaction. As already stated before, the flexibility for the users is lower, since cars have to be picked up and returned to fixed stations. A free-floating car sharing fleet thus provides a higher degree of flexibility by location-independent car usage: customers are able to localize cars based on vehicle-integrated global positioning system (GPS) e.g. by using a smartphone app (Firnkorn, Müller 2015). They do not have to walk longer distances, if the number of car sharing vehicles is adequate for the operating zone.

The decision to offer a station-based or free-floating service must be made carefully and should be based on the local conditions, which were analyzed in the framework of the previously conducted customer and location analysis. As stated before, one advantage of station-based car sharing is to integrate additional services into the parking stations, like charging points for electric vehicles. Since it was decided to establish a car sharing service based on the *smart fortwo electric drive*, an adequate charging infrastructure is an important factor in the smooth operation of the service. However, the location analysis revealed that the charging infrastructure in Greater Lisbon is already very well developed. Especially in Lisbon the density of charging stations is very high (compare Figure 21), which would ease the operation of a car sharing service based on electric vehicles. A contractual arrangement with MOBI.E, the entity that manages the charging network in Portugal, instead of providing own charging points at the parking stations, is therefore preferable. Hence, the location analysis clearly speaks for the integration of a free-floating car sharing service, since one major advantage of station-based car sharing is irrelevant.

The customer analysis based on the online survey leads as well to the result to offer a free-floating car sharing service instead of a station-based. When the survey participants were asked about features that seem most unattractive in joining a car sharing service, 29.3 percent of the respondents have chosen the option “distance / effort to get to the vehicle”. Survey participants who can imagine to use car sharing wish to have an adequate number of cars evenly distributed within the operation zone, which clearly speaks in favor of a free-floating service. Furthermore, especially the landscape characteristics of Lisbon with its seven hills would prevent people to walk longer distances to a car sharing station. 57.42 percent of the survey participants answered, they would be willing to walk between 1-10 minutes to the next car sharing vehicle. This result serves as a reference to estimate the number of vehicles required for the previously determined service area, using free-floating car sharing.

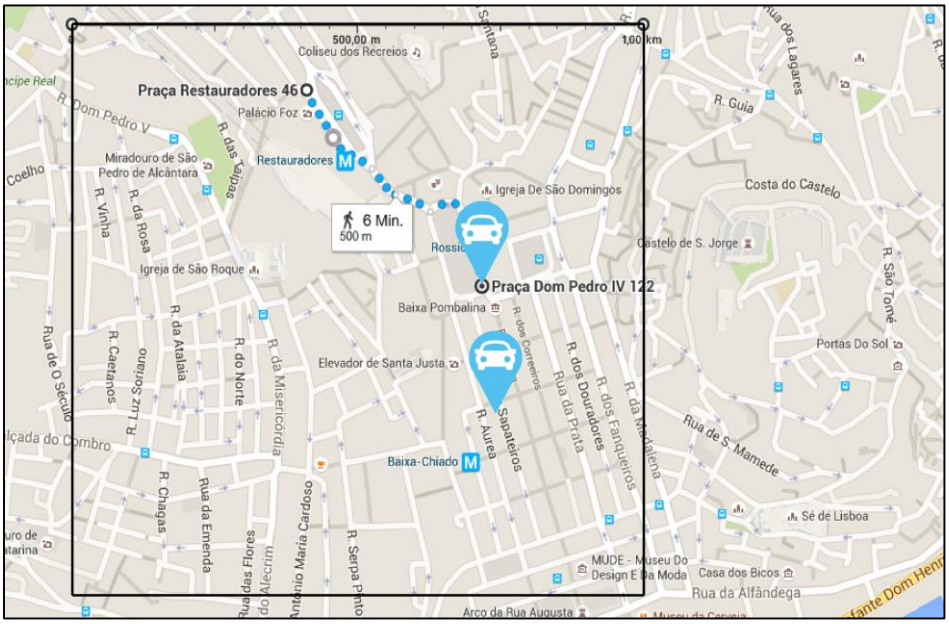

Figure 25. Number of car sharing vehicles estimation

As a first step, the operating range was divided into squares of one km^2 (compare Figure 25), using the distance calculator of the maps tool *google maps*. Afterwards, it was estimated how many cars should be located within a single square, in order to guarantee the wished walking time between 1 and 10 minutes. According to *google maps*, a pedestrian can travel a distance of 500 meters in six minutes. Hence, if it is assumed that cars are evenly distributed within the determined operating zone of Amadora, Odivelas and Lisbon (total area 156.4 km^2), two cars per square kilometer would be necessary to reduce the chance to walk more than 10 minutes. Thus, around 313 car sharing vehicles would be necessary to cover the previously determined operating zone. This figure is of course only a rough approximation, since technological elements on the provider side are hard to evaluate. To determine a more precise amount of vehicles, random parameters, such us customers’ response and competitors’ action have to be taken into consideration. Yoon et al. (2012) recommend in their paper “An Evaluation Method for Designing a New Product-service System” to use a field test in combination with simulation, to reflect

the real environment and to analyze competitor action (buses, taxis, private cars, and subway), which allows to draw conclusions on the expected demand.

7.3.2 Rental Transaction

It was worked out previously that a free floating car sharing service based on the *smart fortwo electric drive* will suit the local requirements of Amadora, Odivelas and Lisbon best and is most likely capable to reduce the negative effects (local and global) of road traffic, which were identified in Chapter 2.2.2 and 2.2.3. As a next step, the precise rental transaction of the car sharing service will be described in this section. The rental transaction comprises seven steps, whereas the first step, the pre-registration, only needs to be carried out once; these steps are described in the following.

1) Pre-registration

Before using the service, the user must go through a pre-qualification in order to verify his / her identity and driver license. The registration is done online – users have to register on the provider's webpage and to deposit name, address and age. The obligation to quote the Portuguese fiscal number during the registration process is not mandatory, in order to allow short-term visitors (e.g. Erasmus students or tourists) the access to the service. Afterwards, the original ID and driver license have to be presented to a service staff member in a local office. At this meeting, the user additionally obtains a personal ID number and has the chance to acquire a RFID (radio-frequency identification) card for a small fee, which allows keyless access to the service vehicles without having a smartphone with internet access. A collaboration with the public transport operators in Greater Lisbon (Metro, Carris, CP, Transtejo and other transport operators) is planned (not easy to realize due to governance struggles), in order to allow customers to use the *Lisboa viva card* to access car sharing vehicles. This would allow a totally integrated and comprehensive transportation network in Greater Lisbon, enabling customers to easily choose between busses, metro, ferries and car sharing.

2) Find

After the user has successfully completed the pre-qualification, he is able to use the service autonomously without interacting with a member of staff. To start a car rental, he has to identify the vehicle nearest to his current position within the operating zone (compare Annex 12). A smartphone application as well as the provider's webpage display the current positions of the car sharing vehicles on a map, as depicted in Figure 25, as well as the position of the user.

3) Book

As soon as the user has identified the nearest vehicle, he can select the car in order to place a reservation. He then has 30 minutes to get to the vehicle, other users are not able to access the reserved car during this period.

4) Access

After the customer has arrived at the car sharing vehicle, he has two different options to access the car – either by smart card (*Lisboa viva*) or smartphone. The *Lisboa viva* card, which has an embedded chip and antenna works by approaching the card to a validator, located in the car sharing vehicle (compare Figure 26). An LED-indicator shows when the car doors are unlocked. The access via smartphone works in a similar way. The provider's application has to be started, which activates NFC (near field communication), and the smartphone has to be approached to the in-vehicle validator. Afterwards, the user has to enter the number indicated on the validator's display in the smartphone application as well as its personal ID number obtained during the pre-qualification step.

Figure 26. Car access via *Lisboa viva* smart card

5) Evaluate

Subsequently, after the user has entered a vehicle, he has to evaluate the condition of the car. A multi-lingual user terminal is integrated in the vehicle, for damage and cleanliness reports. This allows the provider to permanently control the fleet condition and to react fastly on damages and pollutions caused by customers.

6) Use

After customers have gone through the evaluation process, they are able to start the engine. The ignition key is electronically secured and stored in the vehicle. During the use phase, cars can be locked and unlocked with the conventional vehicle key.

7) End

The rental transaction ends, when the user puts the ignition key in the intended position in the vehicle interior and afterwards closes the car doors. Additionally, smart card or smartphone have to be approached to the validator again, in order to finish the rent. The respective amount is debited as soon as the smart card / smartphone approaches the validator. A contractual agreement between the provider and the entity that manages on-street parking intended in Lisbon (EMEL - Empresa Municipal de Mobilidade e Estacionamento de Lisboa) is intended, allowing customers to park vehicles costless in freely accessible locations.

7.4 Obstacles Towards Car Sharing in Greater Lisbon

Despite the potential benefits and drivers of car sharing in Greater Lisbon, there are remaining barriers towards adopting such a product-service system, which were partially identified in Chapter 4.4. However, after the insights of the customer analysis and concept development, a deeper analysis of the barriers focused on Greater Lisbon is conducted in this chapter.

A car sharing business model brings significant corporate, cultural and regulatory challenges, as already observed in the course of the dissertation. Vezzoli et al. (2015) have identified generic barriers towards sustainable PSS on provider and customer side (compare Table 13), which also apply to a car sharing service in Greater Lisbon.

Table 13. Barriers towards sustainable PSS (Vezzoli et al. 2015)

Company side	Customer side
Adoption complex to manage	Lack of knowledge and understanding
Requirement of medium to long-term investments	Lack of general understanding about life cycle costs
Uncertainties about cash flows	Cultural shift necessary
Small and medium sized enterprises are unable to finance such business models	Current trend towards individualization is boosting consumption demand

Adopting a car sharing business model is complex to manage and requires expertise in various areas. However, many companies have developed knowledge in one specific field (e.g. product development), which often results in a lack of know-how in service development (Yoon et al. 2012). Thus, PSS design methods and developing processes should be properly developed, according to Yoon et al. (2012), in order to prevent the business model from failing. Furthermore, in contrast to traditional business models, a car sharing service requires medium to long-term investments, which leads to uncertainties about cash flows. Thus, many businesses perceive PSS business models as more risky than product-based

ones (Vezzoli et al. 2015). Especially for small and medium sized enterprises, a car sharing service would be difficult to implement, due to the high financial effort required. The 313 car sharing vehicles necessary to adequately cover the determined service zone could barely be funded from small companies in Greater Lisbon.

The lack of knowledge and understanding of PSS on the customer side may lead customers to misapprehend the benefits of a car sharing service (Vezzoli et al. 2015). This was also confirmed by the conducted only survey (compare Chapter 6.1). Almost 50 percent of the survey respondents confused car sharing with ride sharing. Furthermore, respondents were not aware of the life cycle costs of car ownership and it was therefore challenging for them to understand the potential economic benefits of car sharing. The necessary cultural shift from “owning a vehicle” to “having a transportation need” constitutes a further obstacle towards car sharing, as already identified at an earlier stage of the dissertation. However, survey respondents seemed open minded and interested in such a mobility concept.

Nonetheless, the current trend towards individualization could hinder the adoption according to Vezzoli et al. (2015), since a person’s identity is nowadays defined by the goods he / she owns. Especially cars are still a measure of success in life in today’s modern society.

8 Multi Criteria Sustainability Assessment

After the car sharing concept was elaborated in the previous stages of the present dissertation, a Multi Criteria Sustainability Assessment has been conducted to evaluate the potential contribution of the service model to sustainable development. For this purpose, an assessment tool, consisting of a set of indicators and an assessment matrix was developed in Chapter 5.3. This tool is now applied to evaluate the car sharing concept according to the elaborated criteria, using a 3-level rating scale (+1 [improvement], 0 [no change], -1 [deterioration]). Additionally, if an improvement was detected, it is indicated which of the traffic related SDGs (compare Chapter 3.1.3) is affected by the enhancement. Reference point is, as already mentioned previously, the expected evolution of the environment in Greater Lisbon in absence of a car sharing service and thus the increasing road traffic.

8.1 Assessment of the Ecological Performance

For a better clearness, the assessment of the ecological performance of the elaborated transportation concept was further divided into three categories – emissions, land use and resources and energy. In the following section the impact of the car sharing concept on these three dimensions is described and the final assessment of the ecological performance follows afterwards.

8.1.1 Emissions

Within the subregion of Greater Lisbon, severe struggles with atmospheric pollution were identified in the framework of the problem analysis (compare Chapter 2.2.2). Especially high density areas, like the municipality of Lisbon, were facing problems with excessive PM_{10} and NO_X levels over the past several years. This trend is likely to continue in the next years, according to BUND (2014). One clearly defined goal of the EU SDS, however, is to reduce the gaseous emissions resulting from the transport sector (Eurostat 2015b). A car sharing scheme based on electric vehicles, as it was proposed in the previous sections, could be a step in the right direction in order to reduce the environmental issues resulting from individual transport in Greater Lisbon. A concept based on the *smart fourtwo electric drive* could help to reduce the harmful emissions of PM and NO_X in inner-city areas, which would have a highly positive impact on the quality of life of the people residing within the service area (Amadora, Odivelas, Lisbon). The electric smart does not produce any emissions at all when driving.

The reduction potential of the CO_2 emissions is more difficult to assess, as several factors (e.g. country-specific energy generation, different life-cycle stages of the vehicle) have to be considered. If the energy consumption and thus the CO_2 emissions of the *smart fortwo electric drive* during the manufacturing phase are compared, as it was done in Figure 27, it can be seen that a smart with conventional combustion engine requires lower amounts (around 3 tons less CO_2) of energy during the production. In the use phase however, when driven about 120,000 kilometers, the greenhouse gas potential of the electric version is with 10.4 tons of CO_2 significantly lower than the one of its gasoline-driven counterpart

(14.4 tons of CO_2 [Daimler AG 2016]). If the overall use phase, including the dismantling of the vehicle, is taken into account, 28 percent of greenhouse gas can be saved driving an electric-powered smart (Daimler AG 2016).

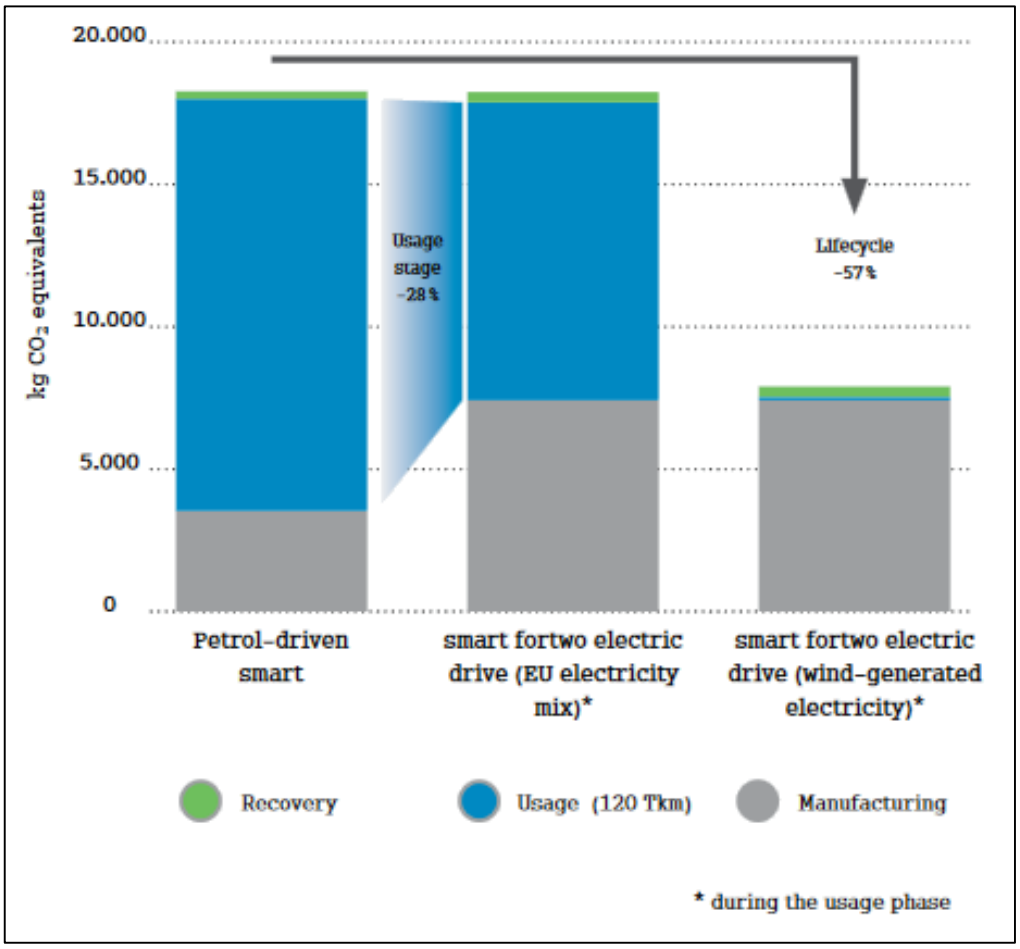

Figure 27. Greenhouse gas emissions comparison (Daimler AG 2016)

However, basis for this scenario was the EU electricity mix, which only partially consist of renewable energies. Another scenario depicted in Figure 27 is operating the electric smart entirely with wind-generated electricity. Thereby, the greenhouse gas emissions over the total lifecycle could be reduced by almost 60 percent in comparison with the conventional smart (Daimler AG 2016).

If the evolution of the share of energy from renewable sources in Portugal is analyzed, there was a moderate but steady increase in the period from 2010 to 2013 (compare Figure 28). This trend is likely to continue, according to Eurostat (2015a), which would result in 31 percent energy from renewable sources up to 2020. However, there is also a specific sub-indicator related to the share of renewables in transport. In this regard, Portugal is one of the countries with less than one percent (0.7%) farthest from the 10 percent target up to 2020 (Eurostat 2015a). Thus, a car sharing concept based on electric vehicles would be a great opportunity for Portugal, since it may help to further raise this share in order to get closer to the target value. The combination of both, a well-developed charging infrastructure for

electric vehicles in Greater Lisbon and the resources for renewables and wind energy in Portugal, may provide a solid basis for sustainable transport solutions in the future.

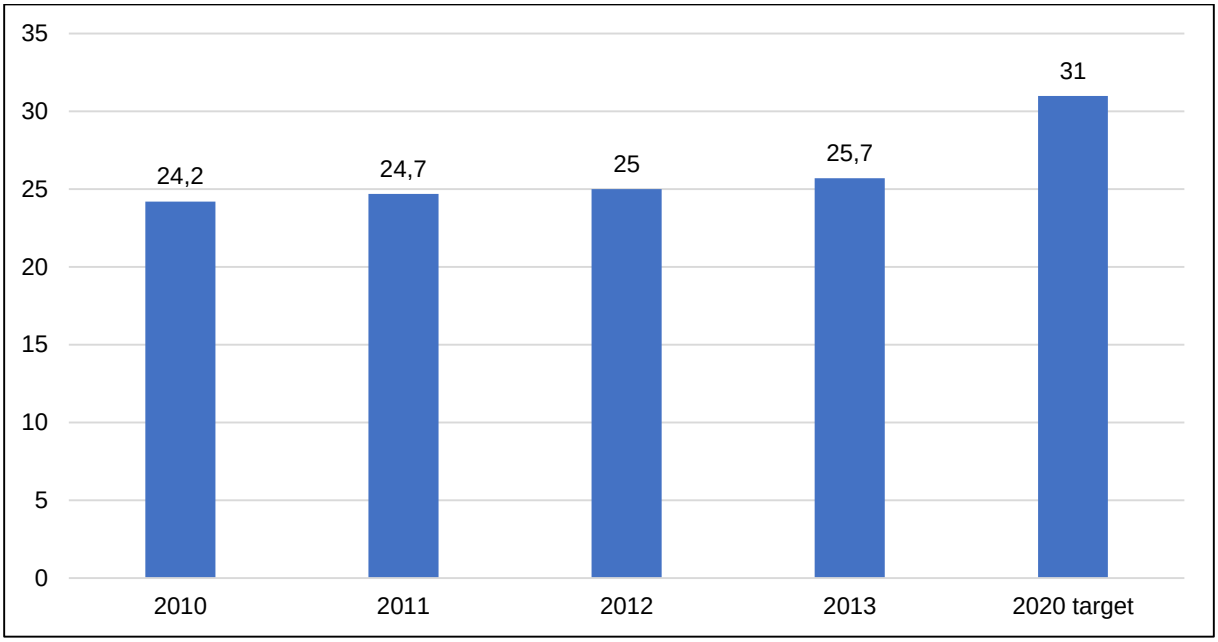

Figure 28. Energy from renewable sources in Portugal (% of gross final energy consumption [Eurostat 2015a])

In addition to the gaseous emissions, dust and abrasion resulting from tire or engine friction could also be reduced, if the concept would be socially accepted and widely used, which should be achieved through meeting local requirements. As the previous research has revealed, car sharing users tend to lower their annual mileage, especially those who decide to totally substitute their private cars by the service. Consequently, the dust and abrasion emissions are lowered as well.

The drive noise of vehicles with purely electric drive is mainly generated by the electric engine. Electric engines are much quieter than internal combustion engines with identical power. Thus, electric cars are barely audible during starting and at low speeds, which would result in a noise reduction, especially in urban areas (UBA 2013). Additionally, as electric vehicles are almost “oil-free”, the soil pollution caused by oil losses may be remarkably reduced, which is naturally only a low-level influence.

8.1.2 Land Use

The changes in land use are more difficult to forecast in the long term. Indeed, car sharing may be appropriate to reduce the traffic density in urban agglomerations, since car sharing users tend to change their mobility behavior, as previously indicated. Especially, a compact vehicle specialized on urban traffic like the *smart fortwo* would be suitable to achieve environmental improvements. Lower road congestions and a higher occupancy rate of the public transport in Greater Lisbon may be the consequences.

However, the landscape fragmentation, which is most pronounced in coastal areas and the municipality of Lisbon, will, realistically seen, not be reduced by a car sharing concept in the near future. At best, a prevention of building up new traffic areas may be achieved in the long-term, which is not predictable though.

8.1.3 Resources and Energy

The required amount of energy during the construction and operation phase of the vehicles will not change, as Figure 27 reveals. Both cars, the petrol-driven *smart fortwo* as well as the *smart fortwo electric drive* produce the same amount of CO_2. However, the data behind the figure is based on the EU electricity mix, which does not take into account the increasing share of renewable energies in Portugal (compare Figure 28). Implementing a car sharing concept based on electric vehicles thus may further increase the share of renewable energies in transport in Portugal in the next decades, which would defuse the situation described in Chapter 8.1.1.

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Figure 29. Components of renewable raw materials and recycled materials (Daimler AG 2016)

Regarding the raw material consumption and the amount of waste and disposal, an improvement may be achieved by operating the *smart fortwo electric drive* as car sharing vehicle. According to Daimler AG (2016), the vehicle “uses primarily materials that consume a minimum of resources and have low energy requirements and a high recycling capacity”. As depicted in Figure 29, 32 different components

are manufactured from “green” materials and further eleven components consist partly or entirely of renewable raw materials (Daimler AG 2016).

Transferring these assessments in the evaluation matrix results in the table below.

Table 14. Ecological performance of the concept

Category		Indicator		Evaluation (+1/0/-1)	Affected SDGs
Ecological	Emissions	1	Change in engine related gaseous emissions (e.g. CO, CO_2, PM, NO_X)	+1	3, 11, 12, 13, 14
		2	Change in other air-pollutant emissions (e.g. dust, abrasion)	+1	3, 11, 12, 13
		3	Change in traffic related noise	+1	3, 11
		4	Change in soil pollution (e.g. oil loss)	+1	15
	Land Use	5	Change in road congestions	+1	15
		6	Change in average public transport occupancy rate	+1	-
		7	Change in landscape fragmentation	0	-
		8	Change in soil sealing	0	-
	Resources and Energy	9	Change in energy consumption (construction and operation phase)	0	-
		10	Change in use of renewable energies	+1	12, 13, 14
		11	Change in raw material consumption	+1	12
		12	Change in amount of waste and disposal	+1	12

Calculating the average contribution to sustainability (9:12) results in a value of 0.75, which means that the elaborated car sharing scheme would bring genuine ecological improvements.

8.2 Assessment of the Economic Performance

The assessment of the economic performance of the car sharing concept was further distinguished between provider and customer side. Furthermore, it was analyzed what would be the effects (positive or negative) on the municipalities of the determined service area.

8.2.1 Provider

Changes on the provider side are difficult to quantify, since only little information is available. Thus, the change in production costs, profitability as well as customer loyalty cannot be evaluated in the framework of the dissertation. However, it should be highlighted that gaining access to the car sharing market in Greater Lisbon could be a major opportunity, since the competition is currently quite low. There is only one car sharing provider operating in Lisbon, which was analyzed in Chapter 6.2.3.

8.2.2 Customer

Regarding the potential cost savings on the provider side, more information is available on the web. As already established during the literature review of the dissertation, joining a car sharing scheme can be financially beneficial, especially for individuals with low annual mileages. This also applies for second-hand cars, as Carsharing-Experten (2016) has revealed in a direct comparison of car ownership and shared car usage. For this purpose, the experts considered two different used vehicle scenarios (small and large car) and calculated the costs per kilometer at the forefront. It was assumed that the vehicles are driven for a period of four years and afterwards sold.

This leads to the following orientation values:

Table 15. Vehicle ownership scaled down to cost/km (Carsharing-Experten 2016)

	Used car, small		**Used car, large**
Annual mileage	5,000 km	Annual mileage	5,000 km
Acquisition costs, scaled down to 1 year (Assumption: 5,000 €)	1,250 €	Acquisition costs, scaled down to 1 year (Assumption: 12,000 €)	3,000 €
Fuel costs (assumption: 6l/100km)	480 €	Fuel costs (assumption: 6l/100km)	560 €
Maintenance, repairs	500 €	Maintenance, repairs	750 €
Insurance	500 €	Insurance	500 €
Taxes	60 €	Taxes	100 €
Resale value 2,000 € after 4 years, scaled down to 1 year	500 €	Resale value 7,000 € after 4 years, scaled down to 1 year	1,750 €
Sum per year	2,290 €	Sum per year	3,160 €
Sum per month	190.83 €	Sum per month	263.33 €
Cost per km	**0.46 €**	**Cost per km**	**0.63 €**

In the case of the small second-hand car (e.g. VW Polo, Opel Corsa), 5,000 € acquisition costs and a resale value after four years of 2,000 € were anticipated. Furthermore, operating costs like fuel, maintenance and insurance were taken into account. Given an annual mileage of 5,000 kilometers thus results in 0.46 Euros per kilometer.

In the second scenario of the large used car (e.g. Audi A4, BMW 3 series) a higher investment of 12,000 € and slightly higher operating costs were assumed, but the resale value is also higher with 7,000 €. The resulting costs per kilometer are 0.63 Euros.

Subsequently, the costs per kilometer of two different car sharing schemes were calculated, taking into account the same annual mileage of 5,000 kilometers and the same time frame of four years (compare Table 16). As one can see from the table, the costs per kilometer of the car sharing services are significantly lower, compared to the vehicle ownership. This cost difference further increases, if new instead of used vehicle ownership is considered, due to the significantly higher acquisition costs and the sharp depreciation in the first years. Thus, it can be concluded that shared vehicle usage may also bring economic benefits for the people residing in Greater Lisbon. Offering a car sharing service based on the *smart fortwo* would allow the provider to offer the service at competitive costs, as the acquisition costs of those vehicles are relatively low.

Table 16. Car sharing usage scaled down to cost/km (Carsharing-Experten 2016)

	Car sharing, scheme 1		**Car sharing, scheme 2**
Annual mileage	5,000 km	Annual mileage	5,000 km
Application fee (500 € deposit scaled down to 1 year, registration 50 €, monthly charge 7 €)	259 €	-	-
Price per kilometer (0.22 €)	1,100 €	Price per kilometer > 20 km (0.29 €)	725 €
Price per minute (0.04 €)	120 €	Price per minute (0.29 €)	870 €
Deposit repayment 500 € scaled down to 1 year	125 €	-	-
Sum per year	1,354 €	Sum per year	1,595 €
Sum per month	112.83 €	Sum per month	132.93 €
Cost per km	**0.27 €**	**Cost per km**	**0.32 €**

The change in expenses for the public transport system cannot be evaluated, since it is too difficult to estimate. However, it can be assumed that the expenses will increase, at least if people decide to substitute their vehicles by the service, since car sharing is not an option that meets the entire mobility needs of a household.

8.2.3 Municipality

The economic changes to the municipality side are closely linked to the previously assessed land use. Hence, the change in transport expenditures like road building or vehicle parking cannot be evaluated, since a car sharing concept in Greater Lisbon will not reduce the expenses for infrastructure in the short-term. However, the costs due to road congestions and accidents may be reduced, since the overall traffic volume may decrease.

A high quality and affordable public transport is the backbone of a sustainable transport system, since car sharing alone is not be sufficient to entirely fulfil the mobility needs of people residing in urban areas. This aspect currently constitutes a noteworthy potential for improvement in Greater Lisbon, since the most important public transport mode, the subway, is very restricted. Hence, it can be assumed that the municipality's subsidies to transport may increase in the next years, not only due to the introduction of a car sharing concept, in order to allow more inhabitants the access to high-speed urban transport. Nevertheless, the municipality could profit from a raising city attractiveness and new job opportunities due to car sharing, which would bring money into the public cashboxes.

The table below shows an overview of the assessment of the economic performance of the concept. Calculating the average (3:10) results in a value of 0.3, which reflects a potential improvement.

Table 17. Economic performance of the concept

Category		Indicator		Evaluation (+1/0/-1)	Affected SDGs
Economic	Provider	13	Change in production costs	-	-
		14	Change in profitability	-	-
		15	Change in customer loyalty	-	-
	Customer	16	Change in operating costs	+1	-
		17	Change in investment needs	+1	-
		18.	Change in expenses for public transport	-	-
	Municipaliy	19	Change in transport expenditures (e.g. vehicle parking, roads)	0	-
		20	Change in external cost of transport activity (e.g. congestion, accidents)	+1	-
		21	Change in subsidies to transport	-1	-
		22	Change in economic revenue (e.g. raising city attractiveness, new jobs)	+1	-

8.3 Assessment of the Social Performance

The social performance of the car sharing concept was further divided in to the subfields "healthiness" and "quality of life" which will be assessed in the following two chapters.

8.3.1 Healthiness

As already established during the assessment of the ecological performance of the concept, trend changes regarding air and noise pollution could be achieved. A concept based on electric vehicles, as it is intended by the author, would be able to avoid / reduce the inner-city air and noise pollution, thus having a positive impact on public health and well-being.

Since car sharing vehicles are usually relatively new and well maintained, the risk of road accidents can be meaningfully reduced, which is of particular importance in Greater Lisbon, where many old and badly maintained vehicles can be seen on the roads. Hence, it can be concluded that the designed car sharing scheme would contribute to healthy lives for all at all ages, as it is demanded by the *2030 Agenda for Sustainable Development*.

8.3.2 Quality of Life

Despite improvements in healthiness, the car sharing concept would have other positive impacts on the quality of life in Greater Lisbon. Inhabitants who cannot afford a private vehicle would gain better access to individual, but nevertheless sustainable mobility, since the high initial investment of car ownership is completely avoided. Hence, the household income devoted to transport may be reduced significantly. Furthermore, job seekers could increase the opportunities for access to employment, if a vehicle is needed for job searching and employment.

Special emphasis was placed on avoiding social differences during the concept development. Thus, accessing the car sharing vehicles would not require a smartphone with internet access. Instead, customers could use the *Lisboa viva card*, which would allow them to easily choose between different modes of transport, like busses, metro, ferries and car sharing vehicles. Thus, the overall transport system satisfaction would increase.

Assessing the overall contribution of the car sharing concept to the social sphere of sustainable development results in an average of 0.875 (7:8), which reflects the highest value in the sustainability assessment.

Table 18. Social performance of the concept

Category		Indicator		Evaluation (+1/0/-1)	Affected SDGs
Social	Healthiness	23	Change in population exposed to traffic noise	+1	3, 11
		24	Change in population exposed to air pollution	+1	3, 11
		25	Change in risk of road accidents	+1	3, 11
	Quality of Life	26	Change in city attractiveness (e.g. lower car traffic)	+1	3
		27	Change in access to mobility (e.g. local coverage)	+1	3
		28	Change in quality of transport for disadvantaged people	0	-
		29	Change in affordability (household income devoted to transport)	+1	3
		30	Change in overall transport system satisfaction	+1	3

9 Reflections and Conclusion

One of the biggest challenges of the 21th century will be to cope with the negative effects of transport, which is also an important issue in Portugal. Within the scope of the present dissertation, the increasing traffic volume in Greater Lisbon was identified as a problem that is caused by different factors, like urbanization and car ownership trends, to mention just two. Based on this evolution, various negative effects on environment and especially on the urban population were recognized in the framework of a deep and intensive problem analysis. The study has shown that road transportation in its present form is undoubtedly not sustainable, since it reduces the quality of life in the city with noise and exhaust fumes, and negatively influences plant species and natural landscape.

However, disadvantages are also given from an economic point of view: recent studies have illustrated that traffic jams are cause for significant financial losses that effect individuals and economies, which are expected to continue to soar in the longer term. The resulting expansion of the road network not only burdens nature, but also the public-sector budgets in the European Union.

The subsequently following research started from the general concept of sustainability and progressed into greater levels of detail – product-service system and car sharing. In this connection, it became apparent that product-service systems are able to contribute to sustainable development, which is one of the reasons car sharing shifts further and further into the center of public interest. It is seen as a mobility concept that may bring various environmental, social and economic benefits. The literature review thus progressed with the analysis of these contributions, whereas the reduction in the annual mileages of the users, as well as the reductions in expenses for transport should be highlighted.

Before developing an own mobility concept for Greater Lisbon, countries with comparable culture to Portugal that already gained first experiences with car sharing were then analyzed. In this context it became clear that the number of car sharing users in Southern Europe is significantly lower compared to the one of Northern European countries. However, governmental support in Italy has led to a steeply increasing number of car sharing members.

In order to propose a car sharing concept for Greater Lisbon that fits the local requirements best, a sort of market analysis was conducted at the forefront, which aimed at exploring the inhabitants' attitude towards shared car usage, as well as the local conditions in the subregion like infrastructure or population density. Greater Lisbon as car sharing site was predominantly judged positive, both, from a location and customer point of view. Based on the insights thus gained shared car usage grounded on the *smart fortwo electric drive* was proposed, and afterwards assessed according to its potential contributions to the three spheres of sustainable development – environmental, social and economic. Special emphasis in this regard was placed on selecting integrated evaluation indicators, which have interlinkages with all three dimensions.

To conclude, it can be said that the proposed car sharing service would most likely contribute to sustainable development in the subregion and could thus be a sustainable mobility solution for Greater Lisbon. The service may counteract the traffic-related issues, since it would be based on electric, small-sized vehicles, which fit especially the cityscape of Lisbon very well. The electric infrastructure within the subregion is fully developed, which would facilitate the introduction of the service. In particular, the combination of both, the increasing share of energy from renewable sources in Portugal and the already existing charging infrastructure clearly speak in favor for the introduction of a car sharing service based on electric vehicles. The emerging car sharing market in Portugal's neighboring country Spain suggests that the demand for economic, ecologic and innovative mobility solutions is already given on the Iberian Peninsula.

One should bear in mind, however, that the idea of shared vehicle usage needs to be further spread within national boundaries. As the online survey revealed, almost half of the respondents were not aware of this kind of product-service system and confused it with ride sharing, a service that brings together potential fellow passengers and people who have free available seats in their cars. Furthermore, one should bear in mind that a high quality and affordable public transport is the backbone of each sustainable urban transport system. This is currently not given in Greater Lisbon, according to the survey respondents. Hence, further investment into public transport should be on the shortlist of public authorities in order to become sustainable in the future. In addition, more cycle paths and sidewalks as supplementary alternative to public transport / car sharing should be constructed prospectively. Financial restrictions could hamper the desired development though.

Finally, one interesting comment about the future vision of mobility made in the framework of the online survey should be taken up again: "Autonomous vehicles […] that will pick you up and drop you wherever you want (like a taxi without a driver)". This comment clearly reflects the future prospect of many car manufacturers, but also companies from outside the sector like *Google* or *Apple* are currently researching autonomous vehicles, with not only technical but also legal questions to consider. Especially with respect to car sharing, autonomous driving could open up new opportunities in the future. The vision of Thomas Beermann, European head of *car2go*, is that people will no longer need self-owned cars in the next ten years within conurbations (FM Autoportal GmbH 2015). As an alternative, in addition to public transport car sharing vehicles are used, which will travel locally free from emissions and partially autonomous (FM Autoportal GmbH 2015). First step will be that users do no longer need to walk to the vehicles. Instead, cars will pick them up at home. An extension of the current business areas would thereby be feasible and economically attractive, since vehicles could move from decentralized to inner-city areas autonomously. Thus, car sharing could be revolutionized prospectively and be able to reach a wider target group, since the distance / effort to get to the vehicle, which was identified as one of the least attractive feature of car sharing within the online survey, would no longer be relevant.

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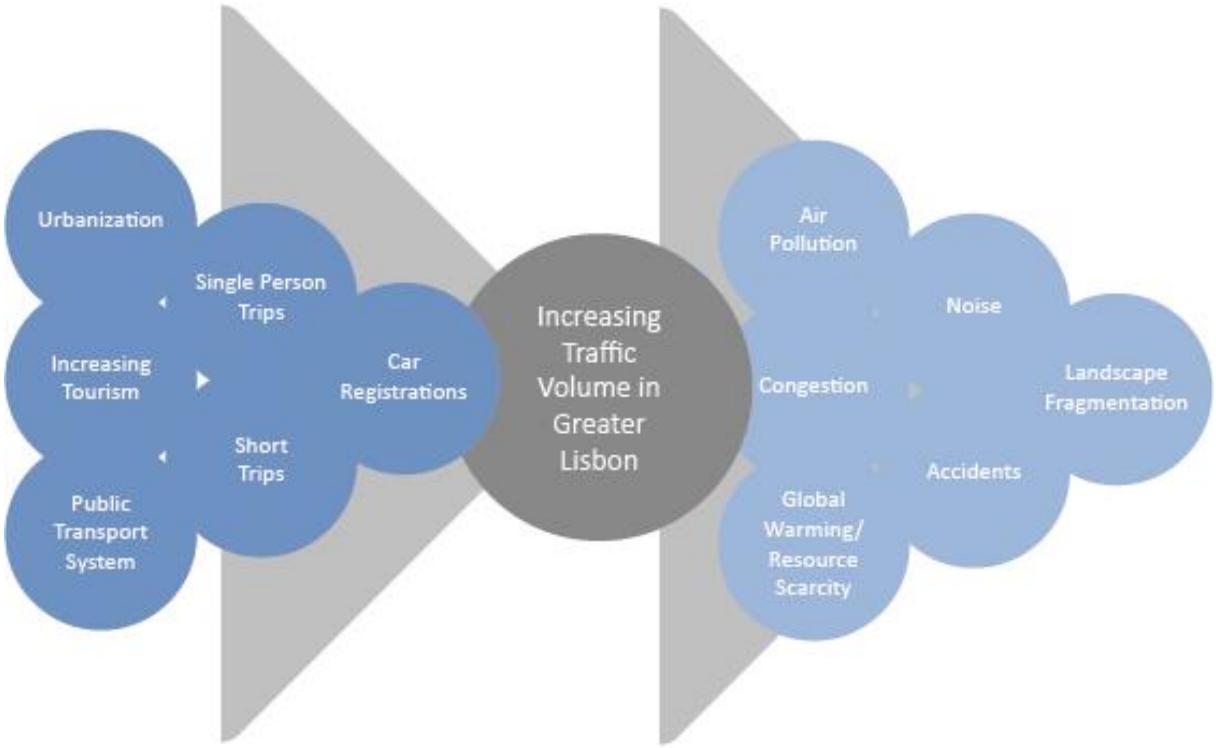
Annex

Annex 1. Causes and effects of the increasing traffic volume in Lisbon



Source: Own graph

Annex 2. The United Nations sustainable development goals

Source: UN (2015)

Annex 3. *Car2go* phone interview results

#	Questions:	Answers:
1	What are the decision-making criteria for the implementation of car2go in a new location?	Adequate population and population density, demographic characteristics, social acceptance (based on research), parking rules and availability of space, agreements with local municipalities
2	Why does car2go currently have only a low presence in Southern European countries (Spain, Portugal)?	Madrid was launched this year and presence in Italy is already high; further cities are explored; currently political changes in Spain and Portugal (inconsistency)
3	Which cities are the ones with the highest usage rate?	Berlin and Vancouver
4	Why does the amount of electric vehicles fluctuate from city to city?	Depends on the availability of charging infrastructure and requires a high investment; Amsterdam and Stuttgart are the cities with the highest usage rate of electric vehicles
5	Is an increase of the amount of electric vehicles planned?	Depends on government regulations (if they are willing to support electric vehicles); an increase of the electric fleet is planned prospectively
6	What are the most common problems with the vehicles after the return by customers (e.g. vehicle conditions)?	Problems refer mainly to electric vehicles (ensure adequate charging level after return)
7	What are the advantages and disadvantages of a low fleet variation (only smart fortwo)?	*Advantages:* Low fleet variation leads to consistency; customers know how the car works; service and maintenance is more cost efficient; easy to handle *Disadvantage:* Smaller target market
8	Is an increase of the fleet variation planned (e.g. forfour)?	In North America and Germany currently runs a pilot project with the Mercedes Benz B-class

Source: William Knapp, car2go (2015)

Annex 4. Car sharing online survey - Page 1

1. What is your age?

- ◯ 18 to 24
- ◯ 25 to 34
- ◯ 35 to 44
- ◯ 45 to 54
- ◯ 55 to 64
- ◯ 65 or older

2. What is your gender?

- ◯ Female
- ◯ Male

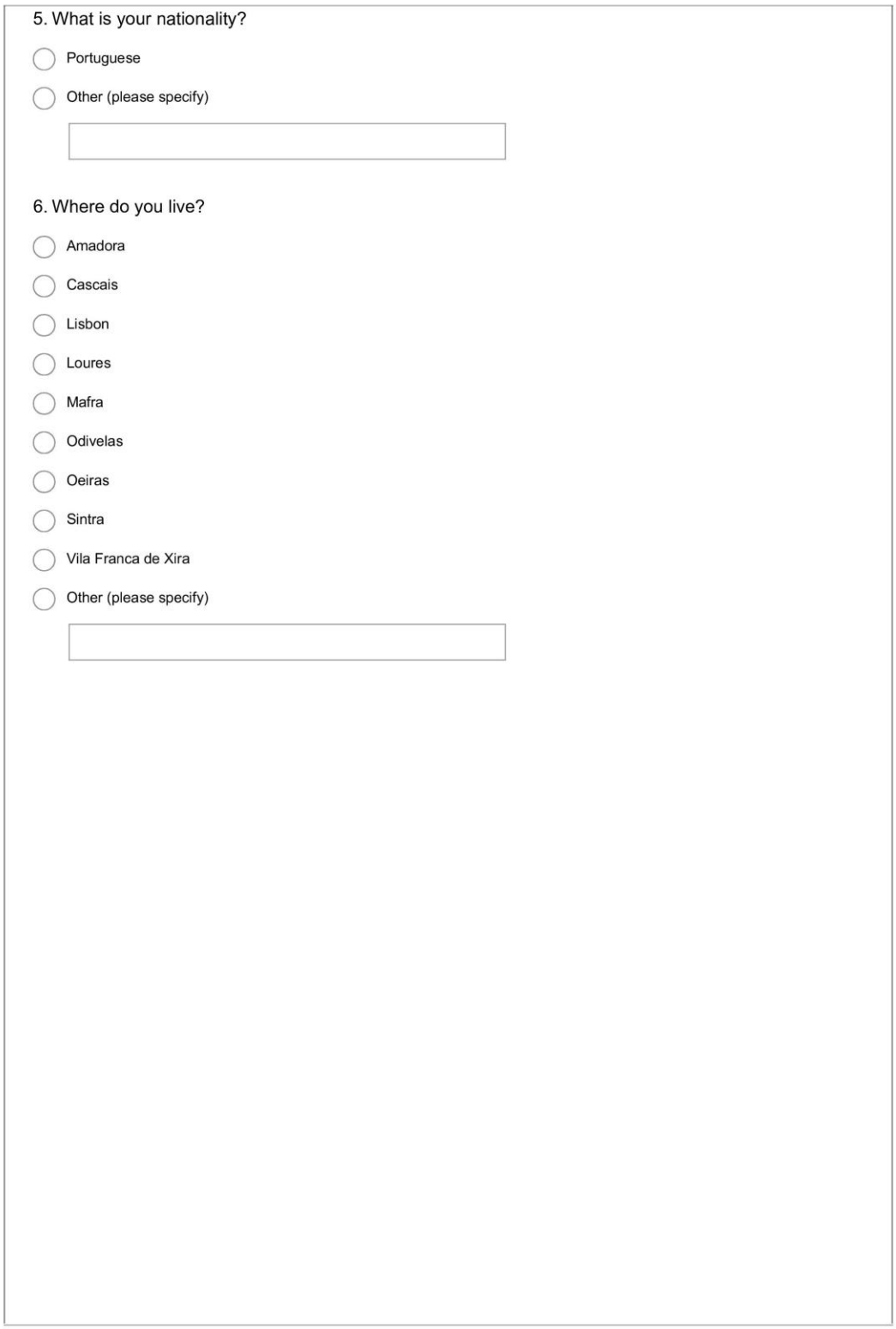
3. What is your profession?

- ◯ Student
- ◯ Professor
- ◯ Researcher
- ◯ Faculty worker
- ◯ Other (please specify)

4. If you are a student / professor / researcher / faculty worker - what is your faculty?

- ◯ Instituto Superior Técnico
- ◯ Faculdade de Arquitectura
- ◯ Faculdade de Medicina Veterinária
- ◯ Instituto Superior de Ciências Sociais e Políticas
- ◯ Faculdade de Ciências
- ◯ N/A
- ◯ Other (please specify)

Annex 5. Car sharing online survey - Page 2



5. What is your nationality?

- ◯ Portuguese
- ◯ Other (please specify)

6. Where do you live?

- ◯ Amadora
- ◯ Cascais
- ◯ Lisbon
- ◯ Loures
- ◯ Mafra
- ◯ Odivelas
- ◯ Oeiras
- ◯ Sintra
- ◯ Vila Franca de Xira
- ◯ Other (please specify)

Annex 6. Car sharing online survey - Page 3

7. Do you have a private car at your disposal?

- ◯ Yes, I possess a car
- ◯ Yes, I use a car available in my household
- ◯ No

8. How often do you use the car?

- ◯ Never use
- ◯ Slightly use
- ◯ Regularly use
- ◯ Daily use
- ◯ N/A

9. What do you use the car for?

	Never use	Slightly use	Regularly use	Daily use	N/A
To make trips to the grocery store	◯	◯	◯	◯	◯
To get to the university / workplace	◯	◯	◯	◯	◯
Visiting family that live elsewhere in the city / province	◯	◯	◯	◯	◯
Holiday trips	◯	◯	◯	◯	◯
Medical-related appointments	◯	◯	◯	◯	◯
Other trips	◯	◯	◯	◯	◯

10. What is the major share of trips you do by car?

- ◯ 1-person trips
- ◯ 2-person trips
- ◯ 3-person trips or more
- ◯ N/A

Annex 7. Car sharing online survey - Page 4

11. How long are the cars in your household driven on an average day?

- ◯ 0-10 min
- ◯ 11-20 min
- ◯ 21-30 min
- ◯ 31-40 min
- ◯ 41-50 min
- ◯ 51-60 min
- ◯ 61-70 min
- ◯ 71-80 min
- ◯ 81-90 min
- ◯ 91-100 min
- ◯ 101-110 min
- ◯ 111-120 min
- ◯ more than 2 hours
- ◯ N/A

12. Cars - what do you associate with them?

- ◯ Cars are status symbols, which reflect e.g. professional success or lifestyle
- ◯ Cars are only one, very convenient, type of transportation
- ◯ Other (please specify)

13. How often do you use the public transport system in Greater Lisbon?

- ◯ Never use
- ◯ Slightly use
- ◯ Regularly use
- ◯ Daily use

Annex 8. Car sharing online survey - Page 5

14. Please evaluate the public transport network in Greater Lisbon according to the following criteria?

	Very good	Good	Neutral	Bad	Very bad	N/A
Availability	◯	◯	◯	◯	◯	◯
Frequency	◯	◯	◯	◯	◯	◯
Price	◯	◯	◯	◯	◯	◯
Reliability	◯	◯	◯	◯	◯	◯
Sustainability	◯	◯	◯	◯	◯	◯

15. What is your understanding of Car Sharing?

- ◯ I give others a ride using my private car (e.g. BlaBlaCar)
- ◯ I can pick up a car at fixed stations in the city
- ◯ I have no idea

Annex 9. Car sharing online survey - Page 6

What Car Sharing is...

Car Sharing is a model of car rental where people rent vehicles for short periods of time, often by the hour. The users must go through a pre-qualification of ID and driving record and are then able to access the service's car autonomously whenever they want, using smartphones or smart cards. The usage is typically billed in time increments of minutes or hours.

The principle of carsharing is that individuals gain the benefits of private cars without the costs and responsibilities of ownership. The vehicles are usually available from distributed locations across a service area. The Car Sharing fleets may consist of electric or conventional vehicles.

The picture below illustrates a service station of the German Car Sharing operator car2go located in Berlin.

16. Could you imagine to use Car Sharing?

- ◯ Yes
- ◯ Not sure
- ◯ No (please specify)

17. How many times would you anticipate using Car Sharing?

- ◯ Once a month
- ◯ Twice a month
- ◯ Once a week
- ◯ Twice a week
- ◯ More than twice a week
- ◯ N/A

Annex 10. Car sharing online survey - Page 7

18. What would you typically use Car Sharing for?

	Never	Slightly	Regularly	Daily	N/A
To make trips to the grocery store	○	○	○	○	○
To get to the university / workplace	○	○	○	○	○
Visiting family that live elsewhere in the city/province	○	○	○	○	○
Holiday trips	○	○	○	○	○
Medical-related appointments	○	○	○	○	○
Other trips	○	○	○	○	○

19. Given you current budget, how much money would you anticipate spending on Car Sharing within a one month period?

- ○ Less than 25€
- ○ Around 25€
- ○ Around 50€
- ○ Around 75€
- ○ Around 100€
- ○ More than 100€

20. Car Sharing services are normally based on a smartphone application. Do you possess a smartphone with permanent internet access?

- ○ Yes, I have a smartphone with permanent access to the internet
- ○ Yes, I have a smartphone but my access to the internet is irregular (only at work, at home, public libraries, etc.)
- ○ No, I don't possess a smartphone with internet access

21. What would be the longest amount of time you were willing to walk from your current position to a Car Sharing location in order to pick up a car?

- ○ 1-5 minutes
- ○ 5-10 minutes
- ○ 10-15 minutes
- ○ 15-30 minutes
- ○ N/A

Annex 11. Car sharing online survey - Page 8

22. Why does Car Sharing appeal to you?

- [ ] It is a good alternative to allow you in the future to avoid replacing a (old) primary or secondary vehicle
- [ ] It is a good alternative to allow you to get rid of your vehicle
- [ ] It is a way to save money on transportation
- [ ] It helps to reduce inner-city traffic jams
- [ ] It is a way to reduce the air pollution in cities, especially if the fleet consists of electric vehicles
- [ ] It does not appeal to me
- [ ] Other (please specify)

23. Would a Car Sharing membership (instead of a private car) encourage you to increase the usage of more sustainable transport modes, such as public transport, walking and cycling?

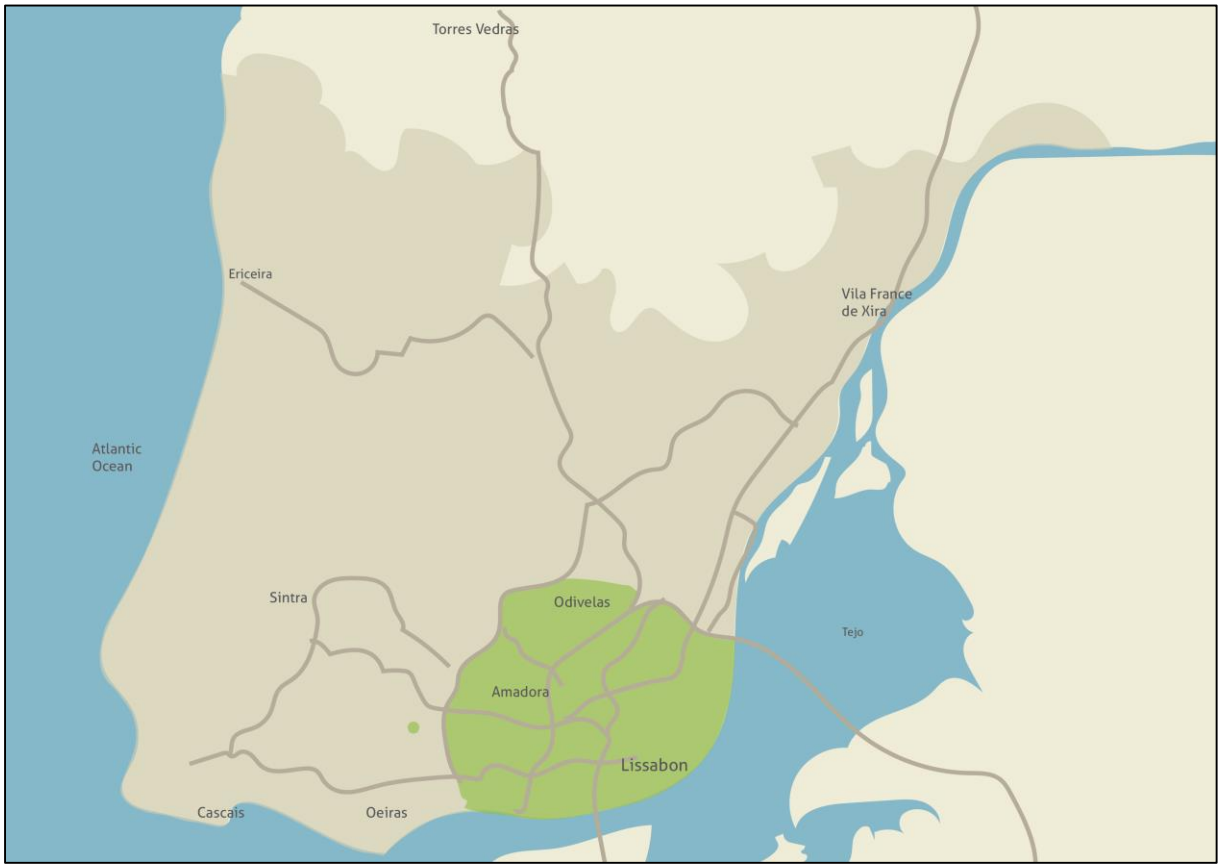
- ◯ Yes
- ◯ No
- ◯ N/A

24. What do you think might be the main disadvantages for you in Car Sharing?

25. What should the perfect Car Sharing service / vehicle offer?

26. Be creative: What are your ideas about future mobility?

Annex 12. Car sharing business area



Source: Own graph