MODEL-BASED DESIGN OF FREE-FLOATING CARSHARING SYSTEMS

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Executive Summary

Within this dissertation a model-based framework and its software implementation as Decision Support System is described which supports decision makers to design free-floating carsharing systems. Free-floating carsharing like DriveNow and car2go emerged as new carsharing concept and shows fast growing rates in Europe and North America. This is expected to continue and expansion to more cities is considered the key industry trend. So far, the local adaptation of the system is based on expert opinions solely. The developed model-based framework comprises the design of the operating area, fleet size, charging concept, fleet mix, and price because these five aspects are identified as key elements when adapting free-floating carsharing to a selected city. In summary, twelve quantitative input variables and five qualitative aspects are modeled as adjusting screws to determine these aspects. The individual models are evaluated where possible and results appear very satisfying. For validation and to ensure applicability, this research also develops a Decision Support System for the execution of the framework. This implementation is demonstrated for Chicago, where a whole new free-floating carsharing system was planned out guided by the developed models.

In a first step, this work discusses key ecological, economical, social, and technological trends which lead to the emergence of a new mobility paradigm. Here, battery electric vehicles (BEVs) and carsharing appear as promising future transportation solutions, also in combination. This is followed by a comprehensive description of carsharing, more precisely, free-floating carsharing. Despite all advantages, such as reduction in traffic, resource use, emissions, and ownership-hassles, there are still some challenges that have to be overcome. First, profit potentials are limited as providers are currently only on the edge to profitability and BEVs potentially worsen the situation by inducing additional costs. Second, the diffusion of the concept is still in the beginning phase and even though forecasts are promising, the diffusion process has to be supported through the provision of market adequate offers, also because customers are very inexperienced. Third and lastly, it is identified that market knowledge is currently very limited. Free-floating carsharing is very new and different from previous approaches. The lack of knowledge on the system poses a problem since expansion to more markets will be the key industry trend in future. Accordingly, the research question is derived as follows: *"How shall free-floating carsharing systems be adapted to different markets/cities?"*

Since every market or city is different, the answer to the research question shall be a model-based framework and its software implementation that supports decision makers to design free-floating carsharing systems city-by-city.

The research design of this dissertation derived three sub-questions from the overall research question. This allows for focus on relevant factors and aspects for the development of the model-based framework.

- Sub-question a) ("which aspects must be locally adapted?"), requires clarification on how carsharing systems are structured. The so-called service marketing mix is chosen as suitable theoretical framework and the debate on adaptation vs. standardization gives a guideline for answering the question. To do so, expert knowledge is gathered through interviews. It is revealed that the operating area, fleet size, fleet mix, charging mode, and the price are main aspects that have to be locally adapted.
- Sub question b) ("how to measure success?") defines success as adoption, which is an individuals' decision to make full use of carsharing. This definition is translated into measurable quantitative variables. As analysis of GPS booking and customer data shows, booking density ($\frac{number\,of\,bookings}{km^2}$) appears as the most appropriate measure for success.
- The analysis of question c) ("what influences success?") is logically based on the same definition of success and hence success factors are defined as determinants of adoption. Here, interviews with experts, companies, and customers are used for a qualitative determination of factors. These factors are argumentatively explored whether they are relevant for local adaptation or not, followed by a quantitative statistical analysis of the remaining factors with the help of booking and structural city data. The result shows that population density, housing rent, city center distance, and restaurant and hotel density are the most influential success factors.

Backed up by these findings the model-based framework is developed, allowing for local adaptation. This is the core result of this dissertation and answers the research question individually for each city as the operating area, fleet size, charging concept, fleet mix, and the price can be determined individually for each city with the help of the framework and in application, its implementation in a Decision Support System for experts.

1. The determination of the operating area relies on a regression model based on population density, city center distance, housing rent, and hotel-/restaurant density. Further, qualitative alignment with a city map to validate forecast results, on-street parking possibilities, and the technology and spatial distribution of existing charging infrastructure must be carried out.
2. The size of the operating area is also a input for the second model concerning the fleet size, together with desired values for utilization and spatial coverage of the system. These the three inputs determine the fleet size, processing results from an agent-based simulation.
3. The third model which determines the charging concept contains a threshold value for the decision of whether decentralized charging is feasible or not. To do so, the input of the operating area as well as the number of charging stations in the operating area is considered. This recommendation must then be aligned qualitatively with the spatial distribution and technology of chargers.
4. Model four concerns the fleet mix which also relies on the number of chargers in the operating area. Furthermore, a potential strategic or regulatory minimum percentage of electric vehicles which might have to be employed is considered. This mix of electric and conventional vehicles should then be reviewed qualitatively whether the respective car models fit in with the local vehicle mix and potentially, the fleet mix must be aligned to suit local conditions.
5. The fifth and final model helps to determine the price per minute for a free-floating carsharing system in a city. Quantitative input factors are a base price for adaptation, local taxi costs, local private car costs, and the exchange rate. The modeled price must then be aligned with the chosen fleet mix because for more useful/valuable cars there could be a price premium. Also, competitor prices must be considered in order to position the product correctly. Further, this dissertation carries out an analysis on the willingness to pay of customers, which could act as base price instead of current market prices.

Together, this results in twelve quantitative input variables and five qualitative aspects which should be considered for alignment, being modeled as adjusting screws to determine the five key aspects of this transportation system. The models were evaluated wherever possible and results were very satisfactory. Joined together and considering the interrelatedness of the models, the model-based framework is derived and guides decision makers on the local adaptation of their free-floating systems as it limits complexity and allows to focus on what is important. To bring it in application, a prototype software implementation as Decision Support System is developed. This gives decision makers a powerful tool on hand to plan for the key industry trend, expansion to new markets internationally and out of its niche in transportation. The validity and applicability of the tool was demonstrated on the example of the city of Chicago.

In conclusion, this dissertation entered new territory in many respects as very few researchers dealt with the problems posed by free-floating carsharing. Moreover, carsharing was never approached in the context of holistic local adaptation to a city. This holistic approach is probably the greatest strength of this work since it presents a reference for further research in the many fields that were opened. Moreover, it provides practitioners with a strong tool-set to actually design free-floating carsharing systems and therefore optimize current and future systems with regards to the operating area, fleet size, fleet mix, charging mode, and the price.

Zusammenfassung

In dieser Dissertation wird ein modellbasiertes Rahmenkonzept und dessen Softwareimplementierung als Entscheidungsunterstützungssystem beschrieben, welches Entscheidungsträger dabei unterstützt flexible free-floating Carsharing Systeme zu konzipieren. Free-floating Carsharing Systeme wie DriveNow und car2go erschienen als neue Carsharing Konzepte und zeigen hohe Wachstumsraten in Europa und Nordamerika. Es wird damit gerechnet, dass sich dies fortsetzt und die Expansion in weitere Städte wird als Schlüsseltrend der Industrie gesehen. Bisher beruht die lokale Adaption solcher Systeme lediglich auf Expertenmeinungen. Das in dieser Arbeit entwickelte modellbasierte Rahmenkonzept beinhaltet die Konzeption des Geschäftsgebiets, der Flottengröße, des Ladekonzepts, des Flottenmixes und des Preises. Hintergrund ist, dass diese fünf Aspekte als Kernelemente identifiziert wurden, wenn free-floating Carsharing Systeme an eine ausgewählte Stadt adaptiert werden. Zusammenfassend werden zwölf quantitative Inputvariablen und fünf qualitative Inputs als Stellschrauben zur Bestimmung dieser fünf Kernaspekte modelliert. Die einzelnen Modelle werden wo möglich evaluiert und die Ergebnisse sind sehr zufriedenstellend. Zur Validierung und um die Anwendbarkeit sicherzustellen, wird in dieser Arbeit auch ein Entscheidungsunterstützungssystem erarbeitet, welches das modellbasierte Rahmenkonzept umsetzt. Diese Umsetzung wird anhand von Chicago demonstriert, für welches ein neues free-floating Carsharing System mithilfe der entwickelten Modelle ausgeplant wird.

Als ersten Schritt betrachtet diese Arbeit ökologische, ökonomische, soziale und technologische Trends, welche zur Entstehung eines neuen Mobilitätsparadigmas führen. In diesem erscheinen batterieelektrische Fahrzeuge und Carsharing als aussichtsreiche zukünftige Mobilitätslösungen – auch in Kombination.

Diesem Schritt folgt eine umfangreiche Beschreibung von Carsharing und im Speziellen free-floating Carsharing. Trotz allen Vorteilen wie der Reduzierung von Verkehrsaufkommen, Ressourcenverbrauch, Emissionen oder dem Aufwand durch Besitz eines Fahrzeugs

gibt es noch immer Herausforderungen die gemeistert werden müssen. Zunächst ist das wirtschaftliche Potential limitiert da Carsharinganbieter heute lediglich am Rande der Profitabilität operieren und Elektrofahrzeuge die Situation durch höhere Kosten potentiell verschärfen. Des Weiteren ist die Verbreitung bzw. Diffusion des Konzepts noch immer in einer frühen Phase. Obwohl die Prognosen vielversprechend sind, muss der Diffusionsprozess durch das Angebot adäquater Lösungen unterstützt werden, da die Kunden noch sehr unerfahren sind. Zuletzt kann festgestellt werden, dass auch das Marktwissen der Anbieter momentan noch sehr limitiert ist. Free-floating Carsharing ist noch sehr neu und unterscheidet sich von früheren Ansätzen. Diese Wissenslücke bzgl. des Systems stellt ein Problem dar, da die Expansion in weitere Märkte in Zukunft der Schlüsseltrend der Branche sein wird. Abgleitet von diesen Herausforderungen stellt sich die Forschungsfrage dieser Arbeit wie folgt dar: *Wie sollen free-floating Carsharing Systeme an verschiedene Märkte bzw. Städte adaptiert werden?*

Da jeder Markt bzw. jede Stadt anders ist, ist die Antwort auf diese Frage ein modellbasiertes Rahmenkonzept. Zusammen mit dessen Softwareimplementierung als Entscheidungsunterstützungssystem unterstützt es Entscheidungsträger dabei, stadtspezifische free-floating Carsharing Systeme zu konzipieren.

Das Forschungsdesign dieser Dissertation leitet drei Teilfragen aus der übergreifenden Forschungsfrage ab. Dies ermöglicht die Fokussierung auf die relevanten Faktoren und Aspekte für die Entwicklung des modellbasierten Rahmenkonzepts.

- Teilfrage a) (*Welche Aspekte müssen lokal adaptiert werden*) bedarf zunächst einer Präzisierung, wie Carsharingsysteme aufgebaut sind. Hierfür wird der sogenannte Service-Marketing-Mix als passende theoretische Grundlage herangezogen und die Debatte über Standardisierung versus Differenzierung gibt eine Vorgabe zur Beantwortung der Frage. Hierzu wird Expertenwissen über Interviews gesammelt. Als Ergebnis stellen sich das Geschäftsgebiet, die Flottengröße, das Ladenkonzept, der Flottenmix und der Preis als Kernaspekte dar, die lokal adaptiert werden müssen.
- Teilfrage b) (*Wie lässt sich Erfolg messen*) definiert Erfolg zunächst als *Adoption*, der Entscheidung eines Individuums Carsharing zu Nutzen. Diese Definition wird übersetzt in messbare quantitative Variablen. Die Analyse von GPS Buchungs- und Kundendaten zeigt, dass die Buchungsdichte (Anzahl der Buchungen pro Quadratkilometer) die geeignetste Messgröße ist.
- Die Analyse von Teilfrage c) (*Was beeinflusst Erfolg*) basiert logischerweise auf

derselben Definition von Erfolg und somit werden Erfolgsfaktoren als Determinanten der Adoption definiert. Interviews mit Experten, Firmen und Kunden werden zur qualitativen Ermittlung solcher Faktoren herangezogen. Durch argumentative Exploration werden diese Faktoren beleuchtet ob sie für die lokale Adaption relevant sind oder nicht. Dem folgt eine quantitative statistische Analyse der verbleibenden Faktoren mithilfe von Buchungs- und strukturellen Stadtdaten. Das Ergebnis zeigt, dass Bevölkerungsdichte, Miete, Zentralität (Entfernung zum Stadtzentrum) und die Restaurant- und Hoteldichte die einflussreichsten Erfolgsfaktoren sind.

Basierend auf diesen Ergebnissen erfolgt die Entwicklung des modellbasierten Rahmenkonzepts welches die lokale Adaption unterstützt und das wichtigste Ergebnis dieser Arbeit darstellt. Es beantwortet die Forschungsfrage spezifisch für jede Stadt, da hiermit das Geschäftsgebiet, die Flottengröße, das Ladenkonzept, der Flottenmix und der Preis Stadt für Stadt bestimmt werden können.

1. Die Bestimmung des Geschäftsgebiets beruht auf einem Regressionsmodell das sich auf die Variablen Bevölkerungsdichte, Miete, Zentralität (Entfernung zum Stadtzentrum) und die Restaurant- und Hoteldichte stützt. Weiter ist der qualitative Abgleich mit einem Stadtplan nötig um die Prognose zu validieren. Zudem muss die Möglichkeit des Straßenrandparkens und die Technologie und räumliche Verteilung von Ladeinfrastruktur beachtet werden.
2. Die Größe des Geschäftsgebiets ist neben der gewünschten Auslastung und räumlichen Abdeckung des Systems auch ein Input für das zweite Modell, das der Bestimmung der Flottengröße dient. Diese drei Inputs bestimmen die Anzahl der Fahrzeuge durch die Verarbeitung von Ergebnissen aus einer agentenbasierten Simulation.
3. Das dritte Modell, welches das Ladekonzept bestimmt, beruht auf einem Schwellwert für die Entscheidung ob dezentrales Laden machbar ist oder nicht. Hierfür wird der Input des Geschäftsgebiets sowie die Anzahl der Ladestationen in diesem herangezogen. Die Empfehlung des Modells muss dann qualitativ mit der Technologie und der räumlichen Verteilung der Ladeinfrastruktur abgeglichen werden.
4. Modell vier betrifft den Flottenmix, welcher auch auf der Anzahl der Ladestationen im Geschäftsgebiet beruht. Zudem muss ein potentielles strategisches oder regulatorisches Minimum an Elektrofahrzeugen berücksichtigt werden. Der

sich ergebende Mix aus konventionellen und elektrischen Fahrzeugen muss dann dahingehend beleuchtet werden, ob die jeweiligen Fahrzeugmodelle zu dem lokalen Fahrzeugtypen passen und ggf. muss der Flottenmix angepasst werden um lokale Umstände zu berücksichtigen.

5. Das fünfte und letzte Modell bietet Hilfestellung den Minutenpreis für ein free-floating Carsharing System in einem Markt festzulegen. Quantitative Inputfaktoren sind ein Basispreis als Absprungbasis für die Adaption, lokale Taxikosten, lokale Kosten eines Privatfahrzeugs und der Wechselkurs. Der modellierte Preis muss im Anschluss mit dem gewählten Flottenmix abgeglichen werden, denn nützlichere oder wertigere Fahrzeuge können ggf. einen Zuschlag rechtfertigen. Zudem müssen die Preise des Wettbewerbs betrachtet werden um das Angebot entsprechend zu positionieren. Zusätzlich beinhaltet diese Dissertation eine Analyse zur Zahlungsbereitschaft, welche statt eines tatsächlichen aktuellen Marktpreises einen Basispreis als Grundlage zur Adaption liefern kann.

Zusammengefasst resultiert dies in zwölf quantitativen Inputvariablen sowie fünf qualitativen Aspekten, die zum Abgleich herangezogen werden sollten. Diese Variablen sind als Stellschrauben modelliert um die fünf Kernaspekte dieses Verkehrssystems bestimmen zu können. Die Modelle wurden wo möglich evaluiert und die Ergebnisse sind sehr zufriedenstellend. Zusammengefügt und unter Beachtung der gegenseitigen Abhängigkeiten leitet sich das modellbasierte Rahmenkonzept ab und dient als Leitfaden für Entscheidungsträger für die lokale Anpassung ihrer free-floating Carsharing Systeme, da es Komplexität minimiert und auf wichtige Aspekte fokussiert. Um das Rahmenkonzept in Anwendung zu bringen wird eine prototypische Softwareimplementierung als Entscheidungsunterstützungssystem umgesetzt. Diese stellt Anwendern ein nützliches Werkzeug zur Verfügung um für den Industrietrend der internationalen Expansion in neue Märkte gewappnet zu sein, der auch aus der Nische im Verkehrswesen heraus führt. Zuletzt wird die Validität und Praktikabilität des Tools am Beispiel der Stadt Chicago demonstriert.

In Summe betritt diese Dissertation Neuland in vielerlei Hinsicht, da sich nur wenige Forscher mit den Herausforderungen von free-floating Carsharing auseinandergesetzt haben. Darüber hinaus wurde Carsharing noch nicht im Kontext einer umfassenden Anpassung an eine Stadt betrachtet. Dieser gesamtheitliche Ansatz ist vermutlich die größte Stärke dieser Arbeit, da sie einen Referenzpunkt für weitere Forschungsvorhaben in den vielen behandelten Gebieten bietet. Außerdem stellt sie Anwendern in der Praxis ein starkes Instrumentarium zur Verfügung um free-floating

Carsharing System auszuplanen. Somit können bestehende und zukünftige Angebote hinsichtlich des Geschäftsgebiets, der Flottengröße, des Ladekonzepts, des Flottenmixes und des Preises optimiert werden.

Contents

Chapter 1

Introduction

1.1 Research Context

Motorized private transport is the backbone of modern society and has many advantages such as comfort, flexibility, and time saving. In the last four decades however, its growth became a massive problem because it outgrew infrastructures and traffic congestion was the result. Also the environment is harmed by the steady growth because motorized individual transportation is mostly based on fossil-fuels. Additionally, since the turn of the millennium new challenges fade in the spotlight such as peak oil, societal preference changes, and consequently changed regulations. These challenges together with the emergence of information and communications technology will most likely lead to a new mobility paradigm since challenges have to be met and mobility needs grow nevertheless. It is expected that this new paradigm will be based on sustainable, intelligent not ownership-oriented but need based pay per use mobility services. Currently, two of the most promising innovations in this field are electromobility and carsharing.

This work focuses on carsharing with and without electric vehicles in its newest form, flexible or free-floating carsharing. Here, vehicles are owned by a carsharing provider and held available with a certain operating area in a city. Within this area, vehicles can be picked-up and returned anywhere legal and a pay-per-minute structure covers all associated costs, such as fuel, maintenance, or parking. The first system of this kind became public in 2009 and since then the concept diffused rapidly to 25 cities in Europe and North America. Growing rates and forecasts look promising and so do potential advantages such as the possibility to provide the same or even a better level of mobility than private car ownership to users whilst reducing resource needs, emissions, congestion, and ownership hassles. Accordingly, the main trend within the industry is the international expansion to more cities but a variety of challenges have to be overcome before this becomes reality: The diffusion or market penetration of carsharing is still in the beginning stage as customers know little about the concept, companies know little about the market, and profitability is currently limited. In order to meet these challenges and to enable further expansion, it is necessary to design free-floating carsharing systems that are appropriate for the local context and as a consequence, the following research question was derived:

How shall free-floating carsharing systems be adapted to different markets?

This question is crucial because transportation infrastructures, social structures, and political framework conditions vary from city to city. Up to now, especially these regulatory framework conditions shape the local design of free-floating carsharing systems. Without the provision of on-street parking licenses free-floating carsharing cannot work and therefore, regulations are clearly crucial. But it is not only the local authorities and given structural traits of a city that foster carsharing. When implementing a free-floating carsharing system in a city, there are many aspects a provider has to adapt in order to provide an appropriate transportation system for the respective city. So far, the aspects that must be adapted are unknown, as well as it is unknown how an adaptation must be carried out and by what it is triggered.

Here, practitioners cannot rely on research findings because only few studies deal with free-floating carsharing in general and with this knowledge gap in particular. Therefore, the local design of free-floating carsharing systems – which is vital for the success of this innovation – relies on gut feeling and expert experience only. This leaves much potential for improvement.

Having a research-based and empirically calibrated and evaluated guideline/ framework that helps to adapt free-floating carsharing systems to each city could be of great interest to practitioners. Moreover, the scientific development of such a framework, which this dissertation strives to, could significantly contribute to the body of knowledge in the young field of free-floating carsharing research. No similar approach has been chosen before and furthermore, due to its novelty, the behavior of free-floating systems is mostly unknown to this day.

1.2 Research Objectives

The aim of this research is to develop a model-based framework which supports the local adaptation of free-floating carsharing so that the concept can diffuse and unfold its advantages to our societies under economic constraints. This framework represents the main outcome of this dissertation and is also the answer to the research question.

In order to develop the model-based framework, carsharing systems must be understood first and a literature review on the state of the art is necessary. Following that, a variety of questions have to be answered.

First, it is necessary to know which aspects must be locally adapted and which can be standardized across cities. Therefore, carsharing systems must be structured, the debate of standardization versus adaptation must be understood, and carsharing specific analysis must be carried out. For this, expert interviews are used as data basis.

The second question that must be answered before development is to which objective adaptation strives to or, in other words, what is success and how can success be measured? The notion of success relies on diffusion of innovations theory since the support of the diffusion of free-floating carsharing is at the heart of this research. The derived theoretic definition is then translated to measurable variables with the help of real GPS booking and customer data.

Consequently, the last and third question is: ”what influences success?”. This approach also relies on diffusion of innovations theory and success factors are qualitatively determined through company, expert, and customer interviews and are then quantitatively analyzed with the help of booking and structural city data.

Guided by this background, each determined locally adaptive aspect is modeled individually to be then joined together in a model-based framework because of the interrelatedness of the models and the holistic approach which is necessary to answer the research question. To fulfill its intended purpose and secure its relevance in practice, the main features of the model-based framework should be:

- FOUNDATION: Be based on theoretical foundations
- SUPPORT: Provide decision-makers with focus and understanding for markets
- ADJUSTMENT: Be easily adjustable to keep models up-to-date
- OPERABILITY: Implementation with little costs, training, and computing
- COLLECTABILITY: Input data must be purchasable standard data
- TRANSFERABILITY: Suitable to any carsharing provider and market
- VERSATILITY: Usable for electric as well as conventional vehicles

- DYNAMIC: Adaptable to changes within a city
- APPLICABILITY: Applicable to existing and new markets

To make this research impactful in reality, the model-based framework is implemented in software as a prototype Decision Support System. To demonstrate the applicability of this tool and the framework in general, this research also outlines an application to Chicago, IL, USA.

In summary, the main outcomes of this dissertation comprise:

- Literature review concerning the state of the art in free-floating carsharing
- Literature review on theoretical propositions to answer the research question
- Analysis incorporating a variety of sources and methodologies, revealing new facets on the behavior of free-floating carsharing. This includes findings on:
  - Aspects requiring local adaptation
  - Potential success measures
  - Success factors
- Model development and calibration as well as evaluation for each adaptive aspect
- Derivation of model-based framework by interrelating the individual models
- Implementation of the model-based framework in software
- Validation and application of the framework and the developed software (to Chicago)

1.3 Outline of the Dissertation

The structure of the work is laid out according to the desired outcomes. Chapter 2 explains the context in which free-floating carsharing must be seen in as well as it explains the concept and its advantages. In contrast, also current challenges are outlined and a research gap is identified, followed by the research design. Chapter 3 answers which aspects must be locally adapted, how to measure success, and what influences success through theoretical and empirical analysis. This gives a sound background for development, which is carried out in chapter 4. Here, the model-based framework and its aims are explained in detail and every locally adaptive aspect is modeled. These individual models are then joined in a holistic model-based framework that enables the local adaptation of free-floating carsharing systems. Later in the chapter, also the software implementation and application to Chicago are described. Chapter 5 concludes this dissertation by highlighting the main conclusions and contributions of this research and indicating its limitations which open up possibilities for future research.

Chapter 2

State of the Art

2.1 Chapter Summary

In a first step, the background and context for this research is examined. Key ecological, economical, social, and technological trends are discussed with the result that a new mobility paradigm might emerge, based on low emissions, energy efficiency, and mobility services. Here, battery electric vehicles (BEVs) and carsharing appear as promising future transportation solutions, also in combination. This is followed by a coherent description of carsharing, more precisely, free-floating carsharing. Despite all advantages, there are still some challenges that have to be overcome. First, profit potentials are limited as providers are currently only on the edge to profitability and BEVs potentially worsen the situation by inducing additional costs. Second, the diffusion of the concept is still in the beginning phase and even though forecasts are promising, the diffusion process has to be supported through the provision of market adequate offers, also because customers are very inexperienced. Third and lastly, it is identified that market knowledge is currently very limited. Free-floating carsharing is very new and different from previous approaches and this lack of knowledge poses a problem since expansion to more markets will be the key industry trend in future. Accordingly, the research question is derived as follows: ”How shall free-floating carsharing systems be adapted to different markets?” Since every market is different, the answer to the research question shall be a model-based framework that supports decision makers to design free-floating carsharing systems. The way this dissertation takes from the research question to the model-based framework is outlined in the research design.

2.2 Context

The current mobility paradigm is challenged by major global developments and industry has to react with innovations, particularly for individual transportation. Authors define innovation as ”an idea, material, or artifact perceived to be new by the relevant unit of adoption” [263] or ”not what innovators do but what customers adopt”. [200] There are four major categories of innovations: incremental innovations, radical innovations, new technological systems (systemic innovations), and new techno-economic paradigms. [92, 175] New techno-economic paradigms represent changes in technological systems that are so far-reaching in their effects that they have a major influence on the behavior of the entire economy. A variety of ecological, social, regulatory, and technological drivers, [86, 90] and their effects potentially lead to a new mobility paradigm.

First, ecological drivers are discussed briefly. Nowadays individual mobility is greatly based on fossil fuels. Not only are gases emitted that are harmful to health (nitrogen and sulfur oxide for example) but also CO_2. The accumulation of carbon dioxide together with other greenhouse gases like methane is strongly suspected to be the main reason for the increase of the average global temperature within the last 50 years which has massive effects on the worlds’ ecosystem. [117] Therefore, the United Nations demand from all parties involved to re-engineer the current techno-economic paradigm and implement all necessary measures to reduce emissions as early as possible. [125] Additionally, oil demand will increase and exceed production within the next decades even though the exact year is hotly debated. Since the delivery rate of crude oil cannot be increased significantly anymore and the gap between demand and supply can only be closed by expensive and environmentally harmful non-conventional oils and gases, most likely oil prices will increase in future. Together with the growing dependency on oil suppliers and oil exporting countries, negative effects on economic growth are expected [118] and mobility needs will be affected. [84]

Closely interlinked to these ecological drivers, social drivers play an important role. One major trend in societal developments is the increasing urbanization. [84] In 2009, for the first time more than 50% of the world’s population was living in conurbations and this number might increase to 70% until 2050. [242] Increased traffic density, local air pollution and the lack of parking facilities are growing problems within this development. This goes along with changed customer requirements regarding mobility, challenging the privately owned car more and more. A phenomenon that exemplifies this is that young people show a decreasing interest in the automobile [82] and was first observed in the beginning of the 1990's in Japan, being named *Kuruma Banare* ("Demotorization"). Also in Germany the proportion of customers buying new vehicles at the age between 18 and 29 years was reduced by 50% in 2009 compared to 1999. [60] Next to ecological arguments, this can also be explained by an increasing lack of interest due to changing values of this generation in developed countries. Fast growing and affordable Internet-services replace the need to possess products like cars. [184] Smartphones, for instance, are more important status symbols than cars for many people. [13] Also, a general trend to "collaborative consumption" [78] is observed in many markets, including not only the sharing of cars but power tools, flats, books, etc. [149] This is also referred to as "shareconomy" and becomes increasingly important to society and according to Weitzman, who established the term in 1984, it increases wealth over all societal classes the more the market players share. [256] Moreover, the purchasing power of young consumers will continue to decline in Europe, the U.S. and Japan over the next twenty years, leading this generation to buy even fewer cars [253, 83] whilst mobility needs stay the same or even increase. Hence, multimodality, which is the intelligent combination of different transport modes, is seen as key trend [83] and future mobility needs will have to be addressed through innovative solutions. [7, 88]

Next, regulatory drivers are discussed since governments react to the mentioned issues in many respects on local (e.g. congestion charge in London), national (e.g. bonus-malus system in France) and international level (e.g. EU CO_2-reduction). [87] Especially the reduction of CO_2 is heavily enforced. Staying with the example of the EU, it is sought to reduce greenhouse gas emissions until 2020 by at least 20% compared to 1990. This also affects the limitation of passenger car emissions, which account for 26% of the CO_2 emitted within the EU. [36] As a result, a binding gradual reduction of CO_2 emissions until 2020 to in average 95g CO_2/km for the fleets of automobile manufacturers is decided whilst speculations reach to a restriction between 10g and 35g CO_2/km by 2040. [8] In parallel, incentives are created for low-emission technologies, accelerating the change of the mobility paradigm.

Last but not least also technological changes drive and enable a new mobility paradigm. Advances in battery technology, fuel cell technology, infrastructure developments such as smart grid solutions to flexibly control electrical energy networks, wireless internet, or IT solutions such as car-to-car or car-to-infrastructure communication enable new forms of mobility. This new mobility can be powered by different energy sources and it can have different, more intelligent, forms enabled by new technology, setting also new standards for the customer and the industry.

Taking all these drivers into account, a new mobility paradigm is expected to be the result. It will be based on eco-friendly and efficient innovations in the field of individual mobility related with new, intelligent, not ownership-oriented but need-driven solutions, known as mobility services. [191] Public transport is a part of this solution, but even an excellent public transportation network cannot solve all mobility needs. Bringing travelers not only approximately, but exactly to their desired destination, is a problem that can hardly be solved economically. There are parameters which limit the effectiveness of public transport, for instance service to remote areas, long distances, the transport of handicapped persons, unpleasant weather, and the transport of heavy or bulky objects. [153] Nevertheless, in the automotive industry it is expected that few market players will be able to stay profitable with purely product-related revenues, or in other words, by selling vehicles only. [7, 25]

2.3 Understanding Carsharing Systems

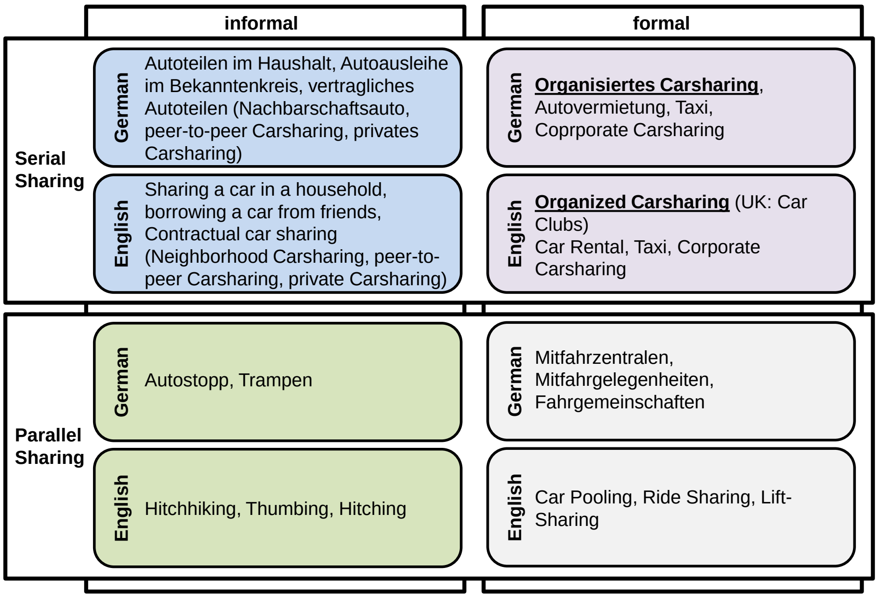
The emergence of a new mobility paradigm will require innovations for future individual mobility and alternatives have to be created, how automobiles will be constructed and how mobility will be shaped in the future. Currently, electromobility and carsharing are seen as likely future scenarios. [220, 89, 88]

Electric vehicles, or more specifically Battery Electric Vehicles (BEVs), enable local emission-free mobility. Once renewable energy is used, also an overall energy efficient and emission free mobility is possible on a well-to-wheel basis [87]. The supply of renewable, emission-free, energy is dependent on regulatory factors that influence emissions trading. [167] If there are appropriate framework conditions, the wide use of electric vehicles could provide enormous ecological and economic advantages in the long term due to their energy-efficiency. Accordingly, governments currently promote electromobility by monetary and regulatory incentives, but their market share is still fractional in most countries. This is because electric vehicles do not yet have competitive Total-Cost-of-Ownership despite lower operating costs. [170] Next to uncertainties in batteries' lifetime, possibly influencing residual values negatively, most vehicles only offer a range of about 100-300km with charging times of up to 8h, depending on the battery capacity and charging power. This becomes even more disadvantageous as there is only very limited public charging infrastructure. Opposed to these realities, customers expect ranges of at least 400km, no comfort losses, and are not willing to pay a price premium [128] and therefore sustainability and exciting driving performance so far do not level out disadvantages for most customers.

Another possible solution within a new mobility paradigm is carsharing. ”Carsharing” means that a car is shared by customers in series (one user after another) rather than in parallel which is known as car-pooling. [23] Figure 2.1 gives an overview on forms and terms in non-ownership car usage forms. This work focuses on modern organized carsharing which is professionally organized by mobility providers, offering different vehicles at different places to their customers. The first documented ”organized” carsharing started in Zurich, Switzerland, in 1948 and operated until 1998 and was known as Sefage (Selbstfahrergemeinschaft). The concept was furthermore often tested but later discontinued in Europe and North America during the 1970’s, 80’s, and 90’s. [212, 151] The breakthrough however happened again in Switzerland in 1987, followed by the first German carsharing operator one year later, Stattauto Berlin. [168, 151] Today, the concept has expanded to approximately 1,100 cities, in 26 nations on five continents. [213] For example, there are approximately 228,000 (traditional) carsharing members in Germany and 100,000 in Switzerland. The concept also manifested itself successfully in other countries like the UK (210,000 members) [94] and the USA (711,290 members). [95] In its functionality, the carsharing concept is intended to fill the mobility gap between public transport, taxis, bicycles, car rental and private cars. [151] It offers the advantage and flexibility of a privately owned car, but without the associated fixed costs and obligations. The permanent ownership is replaced by occasional car usage in order to satisfy mobility needs, e.g. leisure time, shopping, transports, etc. whilst the great majority of ways like going to and coming from work will be traveled by public transport, bicycle, or by foot. [37, 66] This also makes the model attractive to new customer groups.

Whilst the concrete figures of quantitative impacts vary significantly, the qualitative advantages of the mobility concept for the public are agreed upon as follows and approved through a vast amount of studies, e.g.: [160, 103, 142, 213, 151, 50]

- Less parking spaces or occupied areas are needed
- Parking search is simplified (mainly station-based carsharing) and traffic is minimized
- Younger automotive fleets with fewer emissions
- Vehicles are suited to the trip purpose (depending on vehicle availability)
- Reduction in private vehicle ownership



		informal	formal
Serial Sharing	German	Autoteilen im Haushalt, Autoausleihe im Bekanntenkreis, vertragliches Autoteilen (Nachbarschaftsauto, peer-to-peer Carsharing, privates Carsharing)	**Organisiertes Carsharing**, Autovermietung, Taxi, Coprporate Carsharing
	English	Sharing a car in a household, borrowing a car from friends, Contractual car sharing (Neighborhood Carsharing, peer-to-peer Carsharing, private Carsharing)	**Organized Carsharing** (UK: Car Clubs) Car Rental, Taxi, Corporate Carsharing
Parallel Sharing	German	Autostopp, Trampen	Mitfahrzentralen, Mitfahrgelegenheiten, Fahrgemeinschaften
	English	Hitchhiking, Thumbing, Hitching	Car Pooling, Ride Sharing, Lift-Sharing

Figure 2.1: Forms and Terms of Car Usage without Ownership. Adapted from [23]

- Less passenger car use because of cost transparency and changed mobility behavior
- Improved connections to public transport by Park and Ride promotions as well as intermodal mobility concepts (e.g. RegioMobilCard in Freiburg, Germany)
- Easier integration of initial expenses of alternative drives by spreading fixed costs
- Possibility of decreased (CO_2) emissions

Additionally, the customer can always have access to modern vehicles, has smaller or no parking costs and might actually see time savings if there is a high penetration of the service. [17] The stress level of the drivers is then reduced, which is particularly high in large cities. [116] The result, reduced volume of traffic and costs, without necessarily giving up automobile use makes private mobility simpler and mostly cheaper, since it requires no capital investment by the user. As a consequence, it increases social equality because it offers access to a car to people who cannot afford to own one and from a societal perspective, the spread of fixed costs frees up capital that could be spent differently. Finally, carsharing models satisfy the social need for intensified consideration of environmental aspects.

Carsharing with or without electromobility, can be realized in three different ways. The first, traditional approach, works with stations (e.g. public or private parking lots), at which the vehicles must be picked up and returned (A-to-A trips only). Sometimes, these stations are not single parking lots but little areas comprising a few streets and examples for such systems are Zipcar and Flinkster.

Secondly, this approach can be extended as for example DriveNow in San Francisco or Autolib in Paris do. Here, stations are provided where vehicles can be picked up and returned at a different station, enabling A-to-B trips. This theoretically promising concept requires high investment and a high critical mass of customers and vehicles. In Paris, it is configured with 3,000 electric vehicles and 6,600 parking/charging lots at 1,100 stations. [75] In the beginning, the provider did not estimate to be profitable within seven years [9] and the first year even stayed below all expectations and many problems came up. [10] A similar concept, Honda Diracc Car Sharing in Singapore, also faced massive operational issues that lead to unsatisfied customers. In the end, it was discontinued after six years of operation. [45]

A third approach, which was selected by BMW's DriveNow and Daimler's car2go for example, differs from earlier approaches in that the vehicles must be picked up and returned, not at stations but in a defined business or operating area. One way trips are possible since the vehicle can be parked at any legal parking space in this defined operating area; hence, this type of carsharing is called free-floating or flexible carsharing. Figure 2.2 shows the operational principle of such a free-floating carsharing model.

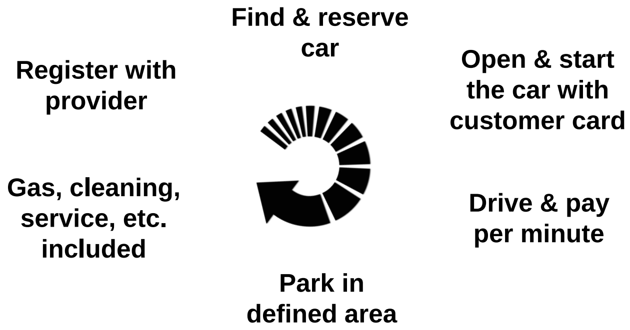


Figure 2.2: Operational Principle of Modern Free-Floating Carsharing

This principle does not emphasize the sharing but the flexible use aspect – a constantly available car fleet fulfilling mobility needs on demand. It intends to be functionally and emotionally equivalent or superior to car ownership and combines the greatest possible customer benefits and flexibility with the smallest investment. Therefore, car ownership can be transformed to car usage without sacrifice. On the downside, the provider must overcome great challenges in making the process work and availability cannot be guaranteed as easy as with reservations because its bookings are spatially and temporally open-ended. [254, 20, 130]

Furthermore, advantages of carsharing (like reduced car usage) are mostly only proven for station-based systems and it is widely discussed whether and to which degree the advantages apply to free-floating carsharing or not. [226, 20, 105] New studies show however, that the advantages of station-based carsharing can be applied to free-floating carsharing concepts as well [79, 80] whilst the quantitative extent is questioned by some experts.

Nevertheless, at this time limited offers and little knowledge about the concept prevent the innovation to be a mass phenomenon but growing rates are promising for the early stage of the diffusion process of carsharing. For example, DriveNow, which started in 2011, attracted in 1.5 years as many customers as all traditional station-based carsharing operators together in 12 years after start of operation (see figure 2.3) whilst car2go, which started as first free-floating offer in 2008, already outgrew traditional carsharing.

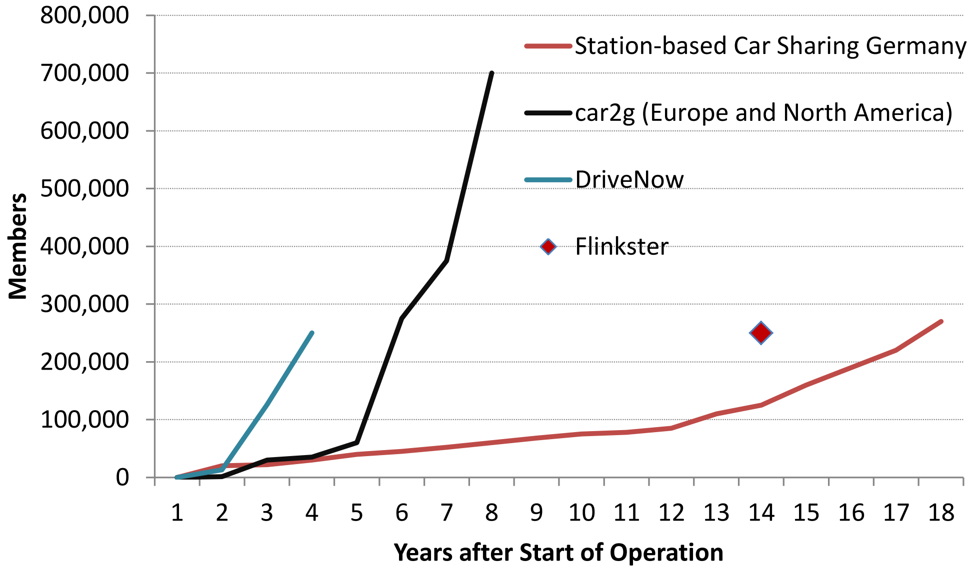


Figure 2.3: Members over Time - Comparing Free-Floating Offers (DriveNow and car2go) with Station-Based Offers [27]

Consequently, free-floating carsharing represents the main focus and data base for this research. To give an overview, figure 2.4 shows a map of cities in which free-floating carsharing is currently offered (as of January 2014). Other variants such as peer-to-peer carsharing or personal vehicle sharing, which provides a model to overcome some of the financial constraints and geographic limitations of fleet ownership and distribution in traditional carsharing, [214] are not considered for this research.

In a next step, combining carsharing with electric vehicles is examined briefly as

Figure 2.4: Map of Cities where Free-Floating Carsharing is Offered

they are both promising solutions for future mobility. In general, two or more innovations are often packaged together to facilitate their diffusion because they have functional or perceived interrelatedness. This is called a technology-cluster or innovation-package [186] and mobility providers around the world prepare for this innovation-package of technology- and service-innovation as they are mutually beneficial:

- BEVs suit carsharing purposes since the range is sufficient here.
- In a mixed carsharing fleet with conventional vehicles all use-cases can be covered, eliminating the need for a second car and thus limiting resource needs. [38]
- Currently high vehicle prices are spread among many users.
- Carsharing lowers barriers to try out BEVs [183] and might offer an alternative to conventional selling or leasing of electric vehicles. [179]
- Carsharing increases the public awareness and acceptance of BEVs [135], acting as catalyst for market diffusion.
- Massive investments in CO_2 reduction [169] could be minimized through electric carsharing fleets.
- Carsharing might affect mobility culture and consequently contribute to a bigger market potential for BEVs [194] as people become more aware when choosing the mode of transportation.
- Since cities pursue the strategy to promote intelligent and intermodal mobility services rather than just promoting a change of the drivetrain of cars [91]; in future, governments might restrict carsharing to electric vehicles only.
- BEVs boost the sustainable image of carsharing systems. [38]

- Being sustainable in all dimensions (3P - People, Planet and Profit) [71] translates to economic success [218, 230] and is considered to be a way for the automotive industry to survive in the long run. [57, 181]
- Vehicle-to-Grid (V2G), where electric vehicles are employed as virtual power storage station [124] could allow carsharing providers to generate revenue even when the cars are not booked. [85, 122, 123]
- In future, operating costs might be lowered due to the lower price of electricity compared to gas once a) vehicle costs are comparable and b) there is a sufficient charging infrastructure since the parking spaces are an incentive for customers to charge on their own, eliminating currently high handling costs.

Nevertheless and despite all the multifarious advantages of free-floating carsharing with and without electric vehicles, there are still challenges that have to be addressed. These are discussed in the following section.

2.4 Challenges for Free-Floating Carsharing Systems

2.4.1 Limited Profit Potentials

The first challenge carsharing faces is the currently limited profit potential. The world's biggest carsharing provider Zipcar for example was founded in the year 2000 but only reached profitability in 2012 [265] which however can also be contributed to the vast expansion strategy. The same appears true for the two existing free-floating providers. According to the head of Daimler Mobility Services, car2go only operates profitably in three of nineteen cities as of 2013. [110] The CEO of DriveNow made a similar statement, indicating that only one of five cities is profitable. [158] As a consequence, as of now the concept itself is jeopardized as it is not economically feasible or sustainable for providers to offer an unprofitable product in the long-term.

The integration of electric vehicles into carsharing fleets potentially worsens the situation and costs are seen as the key challenge for carsharing with electric vehicles. [38] Vehicles must exhibit an acceptable level of Total-Cost-of-Ownership so that providers can afford to infleet BEVs because customers are not willing to pay a price premium for electromobility. [128] Studies show that current costs and structures limit a profitable operation of electric carsharing vehicles. [68] Apart from vehicle costs, charging electric cars is currently expensive since there is no sufficient charging infrastructure in most cities yet. Therefore, charging poses inconvenience and flexibility losses for the customer and must be expensively incentivized or, alternatively, leads to high operational costs for providers if the provider charges the vehicle itself. Additionally, compared to conventional cars, charging needs to be performed more often than refueling (2-3 times a week vs. 2 times per month), requires a new infrastructure, and is time consuming (0.5-8h per charge). To encounter range anxiety, cars should be relatively fully charged for every customer. This increases the charging frequency and times which in turn limit availability and flexibility. As a consequence, bigger fleets become necessary to ensure availability. This increases costs and so do the potential need for a charging infrastructure if none exists.

2.4.2 Limited Diffusion of the Concept

Next to profitability as a prerequisite for the provision of offers, the subsequent diffusion and acceptance of these innovative offers is crucial. According to Joseph Schumpeter, the innovation process consists of three steps: (1) the invention or idea, (2) the development of the invention into a marketable product, the innovation, and (3) the diffusion process where products get spread through an economy, adopted, and imitated. [201] People can be grouped in different adopter categories, which refers to whether an adopter is relatively early or late in adopting innovations compared to other system members. Similar adopters have a great deal in common when it comes to socioeconomic status, media usage, and communication channels. These adopter categories as well as a typical diffusion process are depicted in figure 2.5. Depending on the innovation, the curve can be steep or more gradual. [186]

Whilst in the beginning of the 1990s, similarly to today, an enormous market potential for carsharing was estimated, reality showed only a moderate diffusion of the concept: growing rates were 12 to 30 times lower than expected. [151] Also today, to many the idea of carsharing is still unknown and others are not convinced and skeptical. A study in Germany showed that though 73% of respondents were aware of carsharing offerings, 80% have never used it and only 6% would definitely be prepared to use it. The majority remained undecided, waiting for a better price-performance ratio and better service availability. [188] Similarly, another study showed that 76% of the respondents were aware of carsharing but only 8% of this group dealt with it more deeply and only 2% actually used it. Of those who used it, 84% stated that they could imagine that this form of mobility could replace private vehicles whilst 61% of the total of respondents stated that carsharing is not attractive to them. [6, 12] This disparity clearly shows that the diffusion of the concept is still in its infancy and opinions are

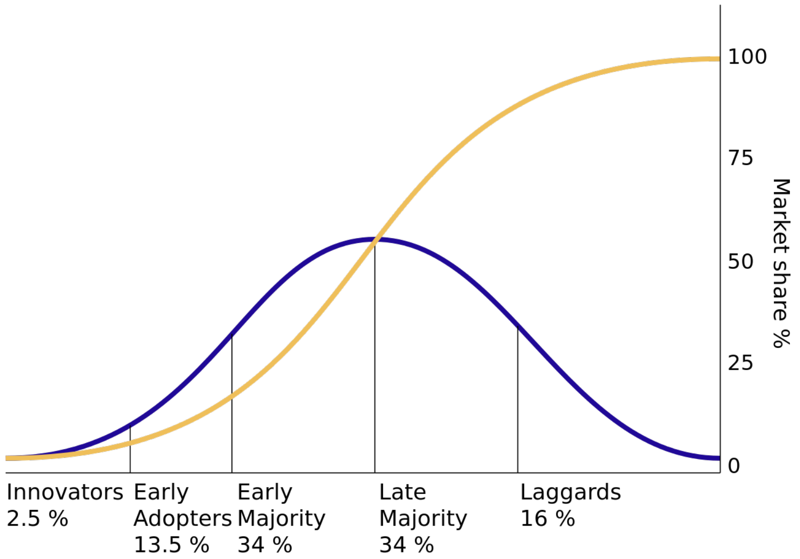


Figure 2.5: The Diffusion of Innovations. The Number of Adopters Depicted in a Frequency Histogram Follows a Bell-Shaped Gaussian-Curve (Dark-Blue). When Cumulating this, the Number of Adopters over Time (the Rate of Adoption) Follows an S-Curve (Brown). [186, 260]

blinded by prejudice rather than actual experiences.

Moreover, since free-floating carsharing only started in 2008 and achieved significant customer numbers and media coverage only by 2011/2012, most opinions are still based on traditional station-based carsharing. Here it was found that diffusion is hindered by missing flexibility and little compatibility to conventional vehicle usage patterns. [151, 203, 224] A flexible system, such as the free-floating concept, should thus not be hindered by these facts in its diffusion, which was also confirmed by a study of Bongardt and Wilke, who concluded in 2008 that a more flexible and modern approach ”seems to be a condition for diffusion in further milieus”. [32] Studies from 2012 assume 9 million carsharing members in North America and 15 million in Europe by 2020 with free-floating concepts as main drivers. [95, 94] Regardless of these promising growing rates, carsharing is still a niche offering compared to around 240 million registered vehicles in Europe in 2010. [76]

Additionally, not only the service innovation carsharing but also the technology innovation BEV is little known. This translates into a fear of novelty and reluctance against the concept. For customers, next to a competitive price, one prerequisite is that electric vehicles develop technological maturity and high reliability since customers do not want to sacrifice convenience. [258] This is unarguably a crucial challenge since several studies demonstrated that one's perception of an innovation determines the rate and likelihood of its adoption [174] or in other words "not the technical change is relevant, but the change of awareness". [108] Nevertheless, studies show that a majority would consider buying an electric vehicle once (subjective) expectations are met. [240]

Since the diffusion of free-floating carsharing is in the beginning stage, it is a niche product in transportation. Forecasts are promising, but the diffusion process has to be supported through market adequate offers to reach further market penetration so that further adoption can become self-sustaining and the concept's various advantages can have a measurable impact in society. Moving from the early stage in the diffusion process – with its own rules and specific customer groups – to the mass market is also economically crucial for providers. This is the gap or "chasm" that innovations must cross to reach the lucrative mainstream market. Innovations that cannot cross this chasm will die or remain niche. [157, 156]

2.4.3 Limited Market Knowledge

The previous sections revealed that in order to unlock the potential of the concept, there must be sufficient offers that diffuse in the market because they meet customers' demands. Thus, these offers will concentrate in areas where high demand is expected. [30] Generally speaking, the market potential depends on user characteristics, framework conditions and the service quality of carsharing and the overall multimodal portfolio in a market. Since free-floating carsharing is very young, operators currently know little about the market and are exploring why their offerings work better in some cities than in other ones but the experience base is limited. Moreover, expansion decisions are often mainly based on the local political situation nowadays. Some cities welcome carsharing providers with the possibility to park vehicles on-street, which is key for a free-floating carsharing operation, whereas others do not allow that possibility. Positive examples include Munich, which allows each free-floating carsharing provider to purchase up to 500 city-wide parking licenses for 1,830 Euro per vehicle every year. [120] Stuttgart and Austin are cities that even offer free parking, [166, 130] and Amsterdam provides a charging infrastructure for E-carsharing. [109] The regulatory framework is therefore a key challenge that must be met with political dialogues in the respective cities (for more detail, see [143]), bringing the advantages of carsharing for society in attention of local decision makers.

Apart from the important regulatory factor, there are widespread opinions regarding success factors for carsharing. Studies often focus on describing socioeconomic characteristics of customers to determine market potential. [225, 30, 161] The average age of mid 30s to mid 40s, incomes in the upper middle class, high education, a predominantly male gender, a below average household size, and below average auto ownership, are typical characteristics of carsharing members. Furthermore, potential carsharing members live in urban areas, are concerned about environmental issues, and are considered to be innovators to which status matters little. [151, 39] Here, forecast customer numbers vary greatly and even a correct estimation of potential customers does not necessarily lead to practical results as the decision to use carsharing depends on many more factors that are not accounted for in sociodemographic analyses. [136]

Next to determining demographic markets, also geographic markets are studied. Here studies vary greatly in results and the number of single households, a high quality of public transportation, little car ownership, and a high population density are often found to be geographic success factors. Obviously, these factors are interrelated with demographic characteristics of users that will be correlated with certain features of the wider neighborhood. [151] With these results, also first attempts were made to assess market potential for certain neighborhoods with the help of a geographic information system (GIS). [49] This assessment however relies merely on location data for stations and does not include booking behavior. This is crucial since offered cars might not be used. An alternative carsharing demand model, based on usage data, revealed that neither population density nor demographic factors play an overt role in the success of carsharing stations. According to the data, rather the age of a carsharing station, commuters that drive alone, street width, households with one vehicle and various public transit variables played an important role. [227] Another approach to combine findings from previous studies was chosen by the BeMobility project in Berlin, seeing population density, car density, public transportation, charging infrastructure, parking pressure, competition, living quality, and the mix of use in an area, as influences for demand. [24] Unfortunately, it is not known how these factors were quantified, weighted, and analyzed to determine areas of high carsharing demand.

Other efforts have been made in the direction to quantify the market potential through activity-based microsimulation to predict carsharing usage while accounting for individuals' travel behavior, carsharing usage, and other forms of travel, [54][1] through a Monte Carlo simulation of the decision to own or share a vehicle, [202]

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[1] This work was later extended to free-floating carsharing, simulating different demand scenarios for Berlin. [55] However, the focus of this work lies on the simulation methodology and the potential environmental effects of free-floating carsharing rather than on market assessment. Also, no empirical data was incorporated.

or through stated preference surveys. [1, 264]

However, all the above approaches are based on station-based carsharing systems. Transfer of knowledge to free-floating carsharing might not be possible since the scale and operating mode is very different. [20] Furthermore, a comparison of booking data of both concepts concluded that temporal and spatial booking behavior is very different - most likely due to different trip purposes. [199] Especially for member prediction approaches it must be noted, that free-floating carsharing is only in the beginning of its diffusion and consequently, current customers are innovators and early adopters, which characteristics are very different from later adopter groups that account for the vast majority of the market. [186] This makes it very hard to estimate the ultimate market size for this innovation. Moreover, if framework conditions are ideal (exclusive access to cities, free-parking, etc.) and the quality of carsharing systems is superb (guaranteed availability, low prices, attractive fleets, etc.), the theoretical market potential could amount to 100%.

Besides this consideration, recent studies concerning the free-floating carsharing market include a gaming simulation exercise and the interpolation of results to estimate the overall potential of the concept for London. [136] Another study provided three separate options for predicting membership in a carsharing program given city demographics: (1) a binary logit model to identify whether a census block will have members or not, followed by a linear regression model to estimate the percentage of population that might become a member in blocks expected to contain members or alternatively, (2) a logit model to estimate the membership percentage. Finally, (3) a Heckman sample selection model was developed to jointly estimate blocks with members and membership percentages in blocks with members, being the recommendation of the author. [130] This approach was later modified by the author by replacing the prediction of membership by a prediction of mode split and trip frequency. [129] However, coefficients of determination were relatively small and as the author points out, predictions might not be transferable to other cities than Austin.

Apart from this latest developments in free-floating carsharing market demand modeling, which have not been evaluated to the author's knowledge, predominant theoretical assumptions are disproved by reality. For example, Calgary (Canada), a city with a population of about one million people, experienced a much more rapid diffusion of car sharing than bigger cities where a bigger customer base and a bigger demand is suspected. [11] This limited knowledge poses a problem to providers when approaching new cities. Expansion, market development, and internationalization are key trends in the carsharing industry. [213] The market choice is essential for the chances of success as carsharing systems are embedded parts of local transportation infrastructures and the place of offering is the place of consumption.

This general market knowledge gap also poses a problem when designing market specific offers for determined new or even existing markets since local customer needs must be fulfilled to suit the environment of the offer. Conditions vary from city to city but it is not only the local authorities and given structural traits of a city that foster carsharing. When implementing a free-floating carsharing system in a city, there are many unknown variables a provider has to adjust in order to provide an appropriate transportation system for the respective city. So far, decisions are based on assumptions and expert knowledge, not on research-based models.

Lastly, providers have limited market knowledge and experience when it comes to electric vehicles in free-floating carsharing systems and the question of how these concepts must be offered to fulfill the local needs of a market must be answered.

2.5 Research Gap

This chapter so far revealed that free-floating carsharing appears as promising solution within a new mobility paradigm; potentially offering many advantages to our society once the concept achieves considerable market penetration. However, there is still a number of challenges providers face in the form of limited profit potentials, limited diffusion of the concept, and limited market knowledge. These challenges are highly connected: For the diffusion of the concept a prerequisite it the availability of sufficient offers, while companies only provide offers when there will be enough customers to enable scale effects and hence profitability. The little market knowledge leads to bad market development, negatively influencing profitability and leaving the customer unsatisfied since companies do not know how and where to provide offers. In short, figure 2.6 provides an overview on the challenges and their interrelatedness, representing a classic chicken and egg problem.

To solve this problem it can be argued whether to focus on all sides of the equation simultaneously or to focus on one single side at a time. Since the three challenges are interconnected, they also evolve around a central question: How can carsharing systems meet market demands? Companies will work out their interpretations of free-floating carsharing systems in order to optimize them and gain competitive advantages

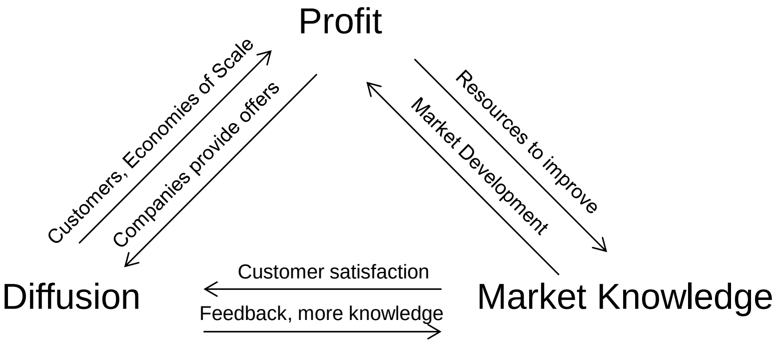


Figure 2.6: Challenges of Free-Floating Carsharing Systems and their Interrelatedness

over other providers. This product differentiation process must be company individual, in order to fit the respective market positioning and internal company structures and strategies. As a result, market needs are fulfilled by different offerings like DriveNow, car2go or Multicity. However, markets can be very different from each other and carsharing is always a local product. This begs the question of ”how can carsharing systems meet *local* market demands?”. In consequence, this poses the main research question of this dissertation:

How shall free-floating carsharing systems be adapted to different markets?

The relevance of the research question becomes clear when looking at possible ways to address the previously derived challenges individually:

- **Challenge 1**: Profitability is jeopardized through technological and operational hurdles, which strongly depend on the local setting - e.g. local demand or to which extent there is a public charging infrastructure or not. This will influence profitability and investigation is needed on how to structure operations depending on the local circumstances.
- **Challenge 2**: Diffusion is only in the beginning stage and in order to meet the optimistic forecasts, providers must meet market demands with their offers. Again, demands and expectations will differ from city to city and offers have to be adapted accordingly.
- **Challenge 3**: The limited knowledge of the market must be expanded regarding the question where to provide offers and how to design carsharing systems to suit local conditions.

Moreover, practice also showed clearly that providers do not have a solid basis for decision-making when designing market-specific offers. So far, everything is based on assumptions and expert knowledge only. Having a model-based decision support that helps to design locally adapted carsharing systems can be of great benefit to all parties involved.

To answer the research question, it must be clarified which aspects of carsharing systems must be adapted to different markets and which can be standardized. To guide local adaptation, there must be an ultimate goal or success definition and measurement to which adaptation efforts are oriented to. Finally, it must be identified which factors influence success. That is a key question for adapting systems locally to the market. It deals with factors that influence whether success becomes reality or not. Hence, these factors are success factors. Only with this knowledge of the market (see challenge 3 above), providers can react accordingly and adapt carsharing systems to these factors in order to benefit profitability (challenge 1) and the diffusion of the concept (challenge 2). In summary, three sub-questions must be answered:

a) Which aspects must be locally adapted?
b) How to define and measure success?
c) What influences success?

To make this research impactful in reality, it is a prerequisite to derive results that are applicable. Only then, the innovation and society can directly profit from this research. Consequently, this dissertation aims to build a model-based framework that helps decision makers to design their free-floating carsharing systems according to local needs. Since all markets are different and there are numerous ”soft” factors which must be considered when determining the local shape of an offer, as for example local politics, it is not aimed by the model-based framework to automatically compute definitive answers but rather to give decision makers a guideline or ”recipe” to follow: ”*An executive is a mixer of ingredients, who sometimes follows a recipe as he goes along, sometimes adapts a recipe to the ingredients immediately available, and sometimes experiments with or invents ingredients no one else has tried.*” (James Culliton, 1948 in [113])

2.6 Research Design and Methodology

This section aims to outline the research design of this dissertation. According to Robson, ”[research] design is concerned with turning research questions into projects”. Primarily, a framework that links purpose, theory, research questions, methods, and sampling strategy needs to be developed. [185] Translated to this dissertation, the research design determines the way from the research question to the model-based framework, which purpose it is to answer the research question. To give an overview, figure 2.7 depicts the research design of this work.

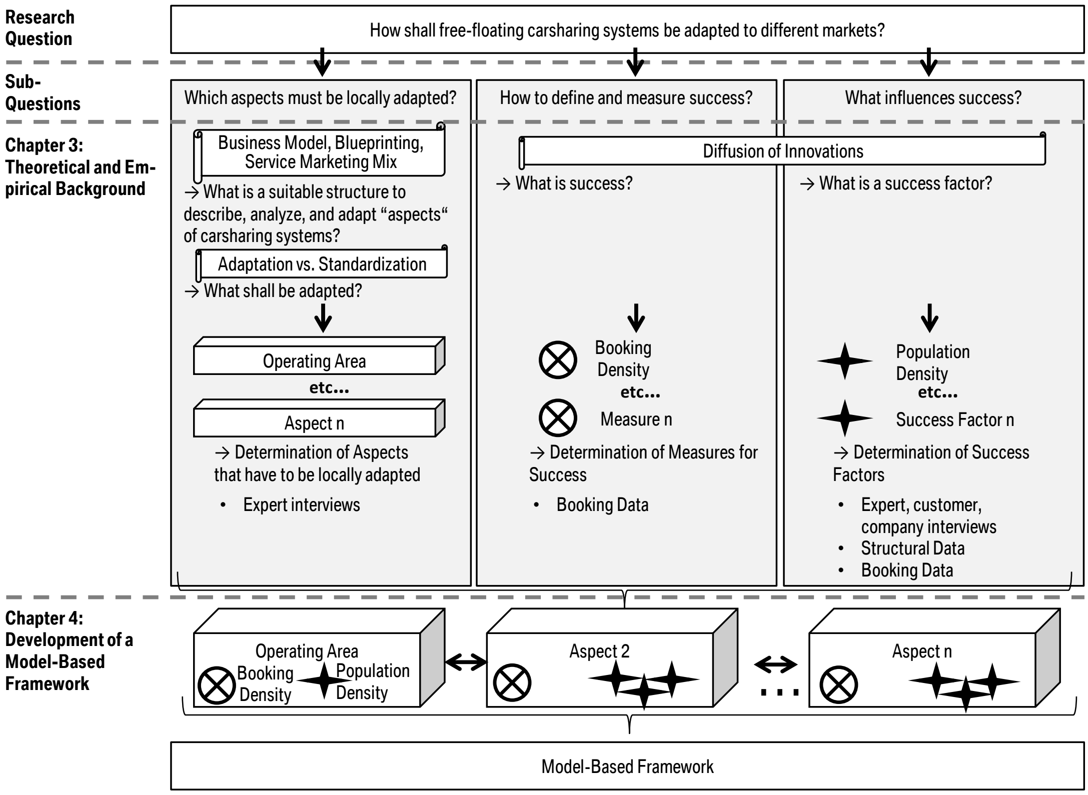


Figure 2.7: Research Design

The initial point of the research design is the research question of *"how shall free-floating carsharing systems be adapted to different markets?"*. As outlined in 2.5, the research question leads to three sub-questions, namely a) "which aspects must be locally adapted?", b) "how to define and measure success?", and c) "what influences success?".

These sub-questions concern different angles of the main research question and further theoretical background and guidance are needed to answer them. Regarding the question of "which aspects must be locally adapted?", Business Model, Service Blueprinting, and Marketing Mix theories are examined in order to find a suitable structure to describe, analyze, and finally adapt "aspects" of free-floating carsharing systems. Next to this, it is necessary to review literature on the question whether to adapt or standardize certain aspects of free-floating carsharing systems. The second sub-question, ”what is success?”, as well as the third sub-question ”what influences success?”, are logically connected and both questions must rely on the same theoretical basis. To determine success and success factors, this research relies on diffusion of innovations theory as it suits best the posed challenges carsharing faces.

Having laid the necessary theoretical background, the gained structure and knowledge is combined in an analysis with empirical data. The ultimate goal of this step is to identify all the relevant input for the development of the model-based framework. According to Denscombe, each research strategy has advantages and disadvantages and some suit better than others for tackling specific issues. [65] For this reason, each sub-question has its individual research methodology as well as different data sources are used, including interviews and statistical analyses of booking and structural data. Because of this complexity and variety of methodologies and data sources, the individual analysis approaches are explained in the respective sections of this dissertation (see 3.2.3, 3.3.2, and 3.4.2) rather than in a central methodology chapter. As a result of this empirical analysis, it is clearly determined which aspects have to be locally adapted, what are the possible measures for success, and what are the success factors. This conglomeration is a prerequisite for the next step.

This next step combines all previous findings in the development of the model-based framework that supports the local adaptation of free-floating carsharing systems and hence answers the research question. To do so, every previously in sub-question a) determined adaptive aspect is modeled individually first, for example the operating area. To model aspects, it is necessary to know the goal of modeling or in other words, what the model should achieve. For this, the analyzed success measures resulting from sub-question b) are used and for example, booking density can be a suitable dependent variable when modeling the operating area. To complete modeling, external success factors or independent variables stemming from sub-question c) must be considered which act as model inputs from the external environment. To follow the example of modeling the operating area, population density could be a potential success factor. However, not all aspects can rely on empirical findings since free-floating carsharing is a very young innovation and data availability is limited accordingly. Therefore, the findings in this report are only partially based on a posteriori knowledge. Other aspects, where no empirical evidence existed or was available for this research, is based on a priori knowledge or justification.

Once all aspects are modeled individually, it is necessary to combine them since many aspects influence each other, e.g. the size of the operating area directly influences the fleet size. This combination of individual models is called model-based framework and it guides decision makers on the local adaption of their free-floating systems. In its functionality, it turns external success factors stemming from the city via a functional unit, containing the modeled logic, into outputs which are the aspects that have to be locally adapted, such as for example the operating area, and therefore supports the design of carsharing systems.

Consequently, the model-based framework seeks to answer the research question of this dissertation and therefore represents the main outcome of it. The precise definition and aim of the model-based framework is detailed in 4.2.

Chapter 3

Theoretical and Empirical Background for Development

3.1 Chapter Summary

The three sub-questions that were derived from the overall research question in section 2.6 provide the structure this chapter is based on since they allow focusing on relevant factors and aspects for the development of the model-based framework. Sub-question a), ”which aspects must be locally adapted”, requires clarification on how carsharing systems are structured. The service marketing mix is chosen as suitable theoretical framework and the debate on adaptation vs. standardization gives a guideline for answering the question. To do so, expert knowledge is gathered through interviews and as a result, the operating area, fleet size, fleet mix, charging mode, and the price are main aspects that have to be locally adapted. Sub question b), ”how to measure success”, defines success as adoption and translates it into measurable quantitative variables. As analysis shows, the number of bookings related to the start point appears as suitable measure for success. The analysis of question c), ”what influences success” (= success factors), must be based on the same theoretical background as the definition of success for which reason they are defined as determinants of adoption. Here, interviews with experts, companies, and customers are used for a qualitative determination of factors. These factors are argumentatively explored whether they are relevant for local adaptation or not, followed by a quantitative analysis of the remaining factors with the help of booking and structural city data. The result shows that population density, housing rent, city center distance, and restaurant and hotel density are the most influential success factors.

3.2 Which Aspects Must be Locally Adapted?

3.2.1 Structuring Carsharing Systems

In order to describe, understand, and analyze carsharing systems to adapt them locally they have to be put in a structure or model. One possible theoretical framework is the business model. There are broad and multifaceted views on the term ”Business Model” and scholars do not agree on what a business model is. [266]

Osterwalder, Pigneur et al. aggregated a wide set of definitions into one broad definition: ”A business model is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm. Therefore, we must consider which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences”. [172] Overall, business models provide a structure to define which activities must work in which way to execute the company’s strategy. Therefore, it is an intermediate structure between the firm’s theory of how to compete and its activities. [182] In other words, ”a business model is the direct result of strategy but it is not strategy itself” [46] and promotes innovation and market success. [234, 119]

To bring free-floating carsharing systems into a structure and to illustrate the design or shape of business models, Chesbrough suggested a mapping approach. [52] To allow for mapping and to consider all relevant components, business model frameworks must be discussed but again there is a variety of opinions when it comes to components of a business model and its configuration. [126] Chesbrough and Rosenbloom argue that a business model has six main functions [51] whereas Stähler argues that a business model consists of four main components. [223] Osterwalder aggregated findings from 14 studies and developed a comprehensive framework composed out of nine components, the Business Model Ontology or Canvas. [171] Applied to carsharing, the business model canvas can look like figure A.1 in Appendix A.

Another possibility of structuring carsharing systems is through service blueprints. Carsharing is a Product-Service-System (PSS) [191] and as every PSS, it ”consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs”. [34] Carsharing focuses on the benefit of mobility rather than the car that enables it, because value is provided through the service component, specifically flexibility. Therefore, service elements overweight.

Services are being characterized as being intangible, non-transportable, consumed immediately, hard to standardize and very individual, and quality assessment is carried out retrospective. [147, 33]

To consider the service component, service blueprinting is a methodology and technique to help address the difficulties of delivering the intangible, facilitating the common understanding of what a firm offers the market. With this technique the service process, points for customer contact, as well as the evidence of service gets sketched simultaneously from the customer's point of view. This benefits the understanding for the customer's role in the carsharing service process, what carsharing users see, and which employee or technology is in contact. It identifies potential points for failure and opportunities and thereafter supports service development, costs, revenue, and capital requirements. It constitutes a rational basis for all marketing efforts and standardizing processes across units. [35, 221] Figure A.2 in Appendix A illustrates an exemplary application to carsharing.

A third theoretical framework for structuring carsharing systems is the service marketing mix, also known as 7Ps. The initial marketing mix as proposed by McCarthy in 1960 consists of 4Ps, namely product, place, price, and promotion and for services another 3Ps have been added: people, processes, and physical evidence. This allows organizations to manage and differentiate brands and other intangible assets, which are utterly important parts of a service firm's value creation. [148]

Rather than being driven by the internal environment like capabilities and competences, staff, or resources, a providers' strategy whether to adapt or to standardize aspects of carsharing systems should be responsive to the external environment. Whilst Business Models and Service Blueprints have a strong focus on the internal environment, the concept of the service marketing mix focuses on aspects that are relevant for the customer and hence for the diffusion or success (as defined in this dissertation) of the concept. It incorporates aspects from Business Model theory (the right side of the canvas) and Service Blueprinting (the visible components) and can therefore be chosen as comprehensive and most suitable theoretical background for this research.

Also, practice and previous research show that the service marketing mix addresses the topic of local adaptation best since it focuses on aspects that are relevant for local adaptation and neglects aspects that are not. McDonald's, being a PSS like carsharing, is the most prominent example, where the 7Ps are adapted instead of the business model. The firm uses an identical look, setting, and operating model in all its restaurants around the globe. Still, its menu is adapted to local tastes. The same is true for carsharing and according to Hillbrecht (in [203]), most operational settings of carsharing models are independent of the local setting for which reason standardized booking software solutions can be marketed worldwide with only minor adaptations according to national bookkeeping and tax standards.

The 7Ps are main elements which consist of a variety of sub-elements. For example, ”price” is not only a single number but also includes pricing methods, sales terms, discounts, etc. In Appendix A every marketing mix element is broken down into its substructure and applied to carsharing. This itemization was guided by a wide set of literature which shall not be concealed: [56, 251, 249, 250, 215, 198, 134, 114, 228]

3.2.2 The Debate on Standardization versus Adaptation

Recalling the research question, the goal of this dissertation is to provide an answer to the question of how free-floating carsharing systems shall be adapted to different markets. Therefore, it is important to understand the debate of standardization versus adaptation which helps to avoid costly mistakes through efficiency loss from lack of standardization, inappropriate products for the intended market, mistakes in improper pricing, or promotional blunders. [100]

This debate started in the early sixties with regard to international advertising, shortly after Buzzel took the debate further by saying it could include not just advertising, but the entire marketing mix. He argued that differences among countries have lead companies to view their marketing approaches strictly as a local problem. Conversely, the situation started to change over time and out of experience a number of firms suggested considering marketing mix standardization for potential gains. [40, 251]

One school of thought generally supports using the same marketing mix worldwide. Global marketers argue that technology is bringing the world together to a ”global village” resulting also in similar needs. One supporter of standardization is Levitt, who believed in low priced, reliable, functional, and advanced products if they are offered on the basis of global standardization. It helps companies to sell at low relative costs and concentrate on what everybody wants rather than losing focus with what people might like. [140] Also, global brands and standardized global marketing are up and coming and could result in higher brand power, consistency, cost savings in production and marketing from economies of scale. [131, 56] Today, it seems apparent that international marketers standardize many of their marketing approaches like packaging and branding across international markets as for example Coca-Cola. [56]

A contrary view is held by followers of an adapted global marketing mix. Here, the producer or provider adjusts the marketing mix to the individual target market, accepting more costs in hope of more market share and return. According to Kotler and Armstrong this idea holds that marketing programs will be more effective if personalized to the unique needs of every target group. [131] Furthermore, this idea applies across international markets, where various cultural backgrounds are the source of different needs and wants, product preferences, shopping patterns, and spending power. These differences are hard to change, which makes the adjustments of marketing mix elements attractive in order to fit the desires in each nation.

The argument that the world is becoming a smaller place and more homogenized might only be true for a limited number of products or service offers, which have minimal product knowledge requirements for use and universal brand recognition. Czinkota and Ronkainen explain that industrial products, i.e. chemicals, steel, agricultural equipment are less culturally grounded and hold fewer adjustments than consumer goods. [56] Nonetheless, it occurs that industrial products experience minor alterations imposed by specific national standards like local regulations (e.g. electric voltage) or different use patterns. [243] Marketers of medical equipment and other technology-intense products find worldwide acceptance with a homogeneous product offering. Also consumer and luxury goods as well as personal care products have a relatively high degree of standardization, whereas food products do not. In general, non-durable goods, e.g. groceries or clothes are very sensitive to cultural differences, tastes, and habits, and are therefore issue to adaptation in foreign markets. [56, 178] Figure 3.1 illustrates and tries to fit in carsharing in these findings.

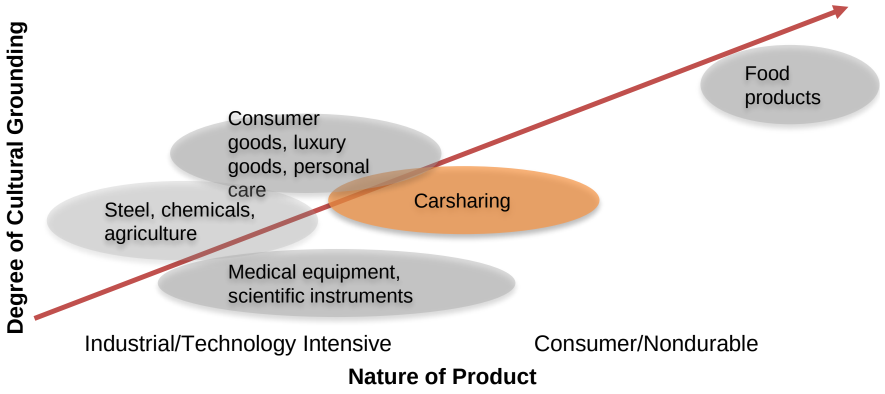


Figure 3.1: Strategic Adaptation of Different Products to Foreign Markets. Adapted from [56].

Cars belong to a group of certain durable consumer goods that can be standardized more easily. However, even if these are less subject to modifications due to the cultural environment, they can require adaptation for other reasons connected to legislation (import), climate (air conditioning), or local technical standards (type of headlights). [243] The carsharing service concept is also assumed to be rather standardizable since cars and consumer electronics (smartphones) are its basis. Nevertheless, the idea of sharing status-loaded cars might be perceived differently in culturally different areas. Moreover, carsharing is an integrated part of local transportation systems which differ drastically from location to location. Therefore, a healthy balance of standardization and adaption must be found and not just on a national but on a local level as every city represents a different environment for transportation. Adaptation as the only solution increases costs tremendously and also leads to consumer confusion. For example an organization offering two completely different concepts of carsharing in Munich and Berlin would lead to misunderstandings, loss in brand recognition and recall, as well as a diluted image. This contingency approach applies for many products and an extreme use of either approach is acknowledged to be not practical. [251, 192]

In order to understand to which degree carsharing can be standardized and must be locally adapted, it is important to review literature on previous attempts to this topic. Specifically for carsharing, whether traditional or free-floating, no literature was found. Similarly, the debate of standardization vs. adaptation is usually seen in an international context [131] rather than looking at a smaller scale such as intercity adaptation. Nevertheless, numerous studies were conducted with other products and industries and this could provide important insights that might be transferred to carsharing. Table B.1 in Appendix B gives an overview on the reviewed studies and figure 3.2 tries to summarize the results of this literature review. These results can be seen as proposed framework for the adaptation of the 7Ps and will guide analysis in the following subsection, where these theoretical propositions are applied to carsharing with the help of expert interviews.

3.2.3 Approach and Data Base

In order to answer the sub-question of which aspects of carsharing systems must be locally adapted, theory gives a guideline. As discussed in subsection 3.2.1, the service marketing mix appears as useful theoretical basis to structure and analyze aspects of carsharing systems in the context of this dissertation. Which of these aspects must then be locally adapted is guided by findings from the debate of standardization versus

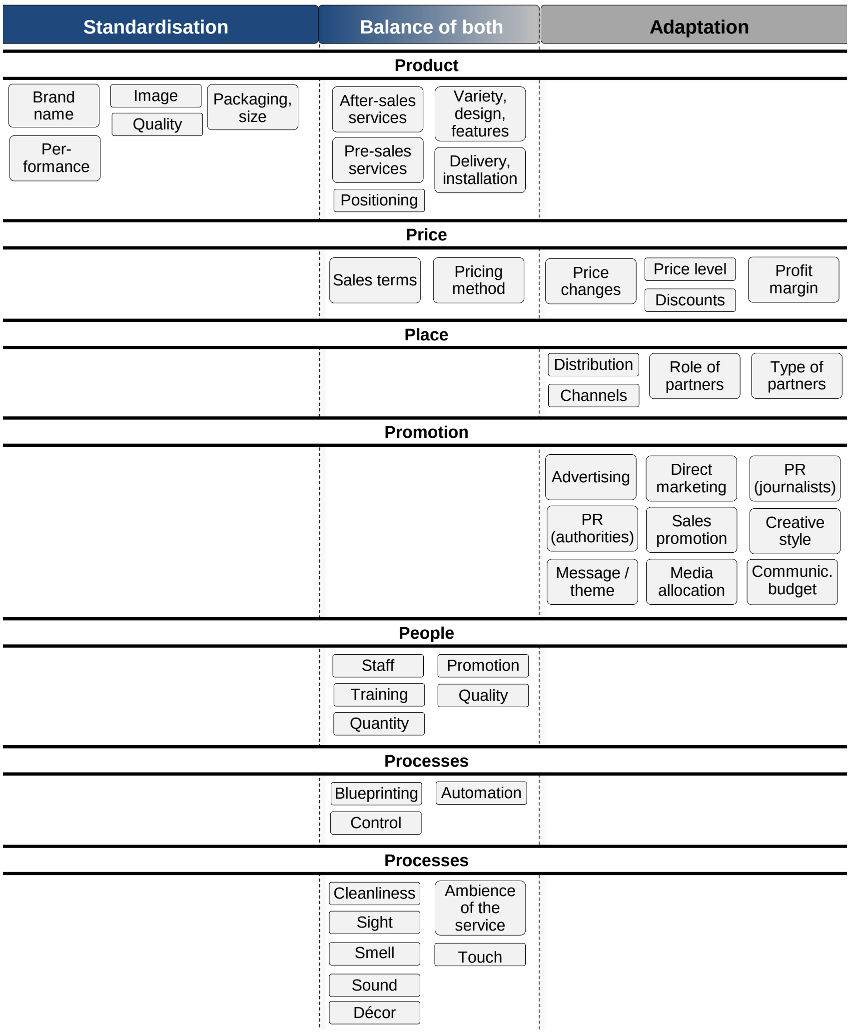


Figure 3.2: Theoretically Proposed Adaptation of the Service Marketing Mix. Based on Studies Summarized in Table B.1 in Appendix B

adaptation, which is presented in subsection 3.2.2. This theoretical background is the foundation for this analysis step since theory has to be applied to the context of free-floating carsharing. Using empirical data in order to answer this sub-question is a challenge because there are only two providers of this very young innovation having offers in multiple cities and only one of them has considerable international experience. Moreover, rather than considering general questions like influential factors for success (see chapter 3.4), discussing the question of ”which aspects must be locally adapted?” means discussing a strategic management decision. Accordingly, many companies will not be willing to reveal their strategy and their reasoning behind.

Generally speaking there are two main philosophies to approach this sub-question, positivism and phenomenology. Positivists tend to use quantitative data and research is replicated repeatedly to reduce errors. This view is generally taken on less complex areas, where repetition is possible. The phenomenological view is more holistic and the resulting conclusion is not necessarily generalizable. Due to the diverse nature of the subject, it tends to rely on qualitative data and studies fewer objects more deeply. In other words, it focuses on the how and why rather than on what and how many. [180] Due to the outlined circumstances and the nature of the object studied, this research follows a phenomenologist view, relying on qualitative data and focusing on carsharing. Outcomes may be similar to other innovations, but the exact conditions and variables are unlikely to be replicated. To generate all in-depth information required for the research's aims and objectives, interviews with experts are believed to be the most appropriate method. Following Glaeser and Laudel, experts hold specific knowledge on the topic and are witnesses of the processes of interest. [102] Advantages lie in the possibility to gain insights into the behavior of organizations and allow for comprehensive comparison of the experts' responses on the topic. [262]

For this analysis, structured interviews are conducted to incorporate findings from theory. A written interview guide, which design is led by the theoretical background given previously, structures the interviews and helps to focus on the main questions of the research. It suggests theoretical findings (see figure 3.2) to the experts who then explain whether they agree or disagree for the case of carsharing. Moreover, it ensures that all data needed is gathered in a similar way. [102] A good guide leads experts not to speak about negligibilities, but to communicate open and to the heart of the topic. [15]

All in all, twelve individual interviews are arranged which is, according to theory, a sufficient number in qualitative interviews to be representative. [152] In these interviews experts from slightly different areas are interviewed, including mobility services strategists, carsharing business developers, the CEO of a carsharing venture and transportation engineering researchers. Nevertheless, the use of multiple sources is limited and certain bias is given, because ten of the experts interviewed work for the same company. This is due to the fact that the topic is quite sensitive. As discussed previously, the question of ”which aspects must be locally adapted?” means discussing a strategic management decision and many companies do not want to reveal their strategy and their reasoning behind.

Following the interviews, data is recorded, stored, analyzed, and matched to theory and the aim of the research. Figure 3.3 depicts the procedure leading to the report, which can be found in detail in Appendix C. The process leading up to the report includes comparing data gained from qualitative research with theory and verifications. Here, changes and extensions to the proposed classifications of marketing mix elements are analyzed. In other words, the data analysis is confirmative as well as exploratory. The gathered data is compared to definitions and empirically based findings from theory to confirm or confute the relevance for this case. Data that does not fit in prescribed definitions is explored to potentially expand given theoretical prescriptions. [146]

Once it is known which aspects should be locally adapted, it must also be decided which of these aspects should be modeled in order to answer the overall research question. This discussion can be found in subsection 3.2.4 and represents the result of this analysis step.

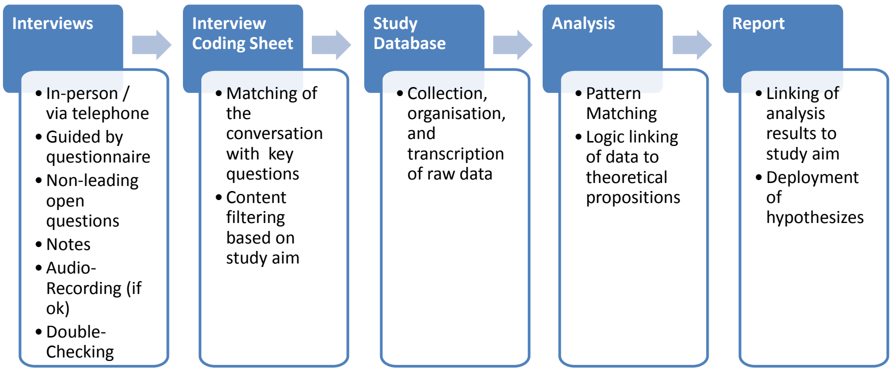


Figure 3.3: Data Gathering and Analysis Procedure

3.2.4 Analysis Results

In general it can be said that organizations cannot know all the little details of every country or city. Experts agree that they must cope with this and standardize as much as possible to limit complexity for the customer and to reduce costs. It is said that standardization is desired to the highest possible degree, especially in fundamental decisions. It is suggested to build on standardized fundamentals and customize further business decisions to local requirements. This becomes key to carsharing, because it is always a city specific product due to given local infrastructures and its individually perceived usability. Also, profitability comes with the application of the learned, so ”teething problems” can be bypassed. In the ideal world, there is one business model and its corresponding marketing mix that is rolled out to every nation and city approached. One of the specialists says: ”Every standardization opens up the possibility to quickly enter a new market. The closer one works along a standardized business model and marketing mix, the shorter is the required preparation time in order to enter a market and the faster can the product be positioned. This happens independent of the needs a local market may impose."

However, it is agreed that adaptation of some marketing mix elements is just as crucial as a uniform approach. One of the experts says: "Adaptation for carsharing is important, not necessarily to differentiate among countries, but to adapt the service offer for every city involved." Carsharing is quite complex and seen as part of the individual city and public transportation system, which demands for variation in every city. Experts also state that the most obvious difference is between industrialized and emerging markets which often lack of a comprehensive public infrastructure for example. Here it is probably necessary to alter the whole business model and free-floating carsharing is not possible. Therefore, this is not scope of this research. But also on a smaller scale adaptation is necessary. For reasons of clarity and comprehensibility the detailed analysis report with explanations and considerations of experts' is outlined in Appendix C.

To summarize the analysis results however, there is a wide variety of locally adaptive aspects even though standardization is sought wherever possible. Most obviously, the language has to be adapted. Also, communication messages are slightly altered to play with different aspects of the image according to local preferences and existing competition. Not only customers but also public relations with authorities must address individual needs and explain why this form of new mobility benefits their city. Accordingly, the creative style must be adapted slightly to address different markets "personally". This all relies on different communication channels, advertising channels and promotion partners as for which reason also media allocation and budgets are adapted, because every country and city has its own budget and media mix. Similarly, also pricing is subject to local adaptation. At this point it remains unclear whether the pricing method is affected but it seems that the pay-per-minute pricing becomes synonym with free-floating carsharing. Individual providers might offer different options like in the mobile phone market, which can then be adapted to local tastes. Similarly, discount policy is reactive to local conditions and requires individual handling and varies over time. Further, also the profit margin differs locally but is result of other marketing mix elements rather than of intentional adaptation. Nevertheless, it appears important to set city individual goals to avoid comparing apples to oranges. Further, it is found that internationalization makes different partners necessary, which also leads to different roles of the partner and different registration stations or registration concepts. Besides, this results in a different décor as it is mostly not actively driven by the carsharing organization and depends on the varying local partners. These partners can also be helpful in understanding different legal requirements, e.g. license verification, changes in terms and conditions, locally common payment methods, or different hiring processes. The quantity of operating staff is always adapted to the size and service needs of the respective city and it is important to hire local people with local knowledge, which is crucial to complement standardized processes. Further, locals stick to local customs and know how to interact.

All the aspects above either demand creativity from carsharing providers or are simple items on a ”things to do list”. Other aspects that were identified are very complex however, and require further examination and modeling. The aspects that have to be modeled include first and most obviously the operating area as every city's form and structure differs. Second and closely interrelated, the fleet size is adaptive as well. Third, a city's charging infrastructure is never the same which must be addressed by adapting the charging concept to the given conditions. Equally and fourth, the fleet mix must be modeled regarding to which mix of drivetrains shall be applied to a city to fulfill local requirements best. On an international level, the fleet mix regarding the kind of vehicles might have to be adapted slightly as well, which is subject to discussion in the respective chapter. The fifth and last aspect that has to be modeled is the price level which should stay the same within a currency zone but has to be adapted internationally.

In chapter 4, these five individual models will be developed and then be joined in a framework - the model-based framework which represents the main outcome of this dissertation.

3.3 How to Measure Success?

3.3.1 Defining Success

This section deals with the definition of success which is also a prerequisite for finding factors that influence success in the following section. The reasoning behind the search for factors that influence success is self-explanatory as every venture aims to be successful. Researching success factors is of high practical importance as the knowledge about drivers of success is an important knowledge base for managers to base their decisions on and to measure the impact of decisions made. Key to the concept is the conviction that the multidimensional and multicausal success of a venture, in this case carsharing, is credited by a few central factors - success factors. [197] The concept was first introduced by Daniel in 1961 [61] and since then a vast amount of empirical works was concerned with the investigation of determinants for success. Thus, success factor research can be regarded as an independent and empirically oriented research approach that can be focused on a variety of analysis objects, success definitions and measured variables, research methodologies, and analysis methodologies. [197]

Before determining success factors, the dependent variable that represents success must be specified. To do so, the notion of success must be defined as it could comprise in quality measures, reduced congestion, financial performance, user satisfaction, operational efficiency, and so on. This work understands success as a scenario where carsharing (potentially with electric vehicles) is diffused to our societies so that its advantages can be unfolded, satisfying all stakeholders - providers are profitable, offers meet markets' demand, cities' traffic problems are reduced – and a new mobility paradigm has arrived. This however is not a very clear definition of success and section 2.4 revealed that a variety of challenges that have to be overcome before this could become reality:

a) Profitability is jeopardized
b) The diffusion of free-floating carsharing is still in the beginning stage and must be supported
c) Companies know little about the market

It was also derived that the local adaptation of carsharing systems addresses these challenges and in order to know how to adapt, a key is to know which factors influence the decision to use carsharing. According to Rogers, an individuals' "decision to make full use of an innovation as the best course of action available" is defined as adoption. [186] From this it follows that **adoption is a good notion for success** because it targets the three main challenges of carsharing:

a) Profitability. Knowing how to stimulate diffusion (see b)) and satisfy markets (see c)) translates into more revenue which could lead to scale effects and profitability. Moreover, Mansfield showed that the speed of diffusion is positively related to the profitability of adoption. [144]

b) The limited diffusion. Referring back to Schumpeter [201] adoption follows a process in an economy, the diffusion, which is consequently a process of individual adoptions. Following this, knowing what influences adoption means knowing what influences diffusion.

c) Companies' limited market knowledge. Knowing about local influences on customers' decisions to use the concept means knowing the market.

Once carsharing is adopted by more people, it reaches a critical mass and enough individuals have adopted so that further adoption is self-sustaining. [186] This leads to positive feedback effects (e.g. better financial results and better environmental effects) and consequently to holistic success – close to the previously described success scenario.

3.3.2 Approach and Data Base

Since success was defined as adoption or an individual's decision to use carsharing, the desired outcome can be translated to how many people decide to use carsharing (=number of customers), how often individuals decide to use carsharing (=number of bookings), and also how intensely they decide to use carsharing (=duration of bookings). This logically translates in the key revenue streams of carsharing providers since adoption and profitability are strongly related. This approach is summed up in figure 3.4.

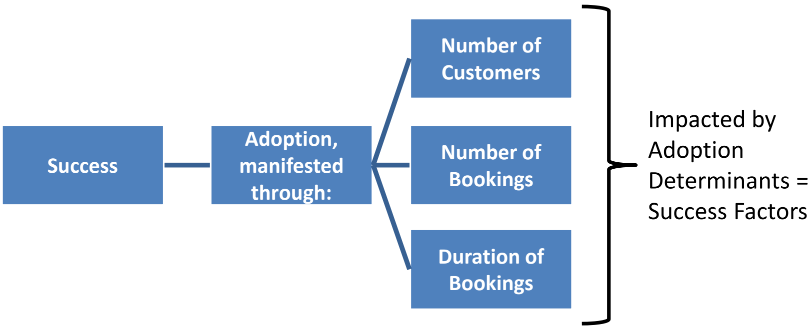


Figure 3.4: Measures of Adoption as Possible Manifestations of Success

These variables are "dependent" on "independent" adoption determinants (success factors) as previously described. Also, in order to enable local adaptation, potential dependent variables must be suitable for being geographically assigned to certain parts of the city to highlight more successful locations. Each of the three adoption measures can be geographically represented as density, e.g. customer density in an area. In order to find the most important of these three potential variables and to be able to interpret them as well as upcoming analysis results, the next section will quantitatively describe them with the use of descriptive statistics.

Unlike most transit agencies, which are the subject of the vast majority of transportation research, carsharing is a competitive industry. This competitive nature has important implications for this research, because much of the detailed information on member characteristics and operational performance is considered proprietary by carsharing operators. [151] For this dissertation however, a data base was provided by DriveNow, a premium free-floating carsharing provider which launched operations first in Munich (June 2011), followed by Berlin (September 2011), Düsseldorf (January 2012), San Francisco (August 2012 but as an A-to-B station-based system), Cologne (October 2012), and Hamburg (November 2013). The premise for choosing the data base is to rely on a sufficiently long analysis period while possible run-up and seasonal effects should be cut out. Hence, a 12 month period starting a while after the launch of a city appears best. Given the potential dataset for this research, only Berlin and Munich offered suitable data while Düsseldorf appeared as an attractive data source for evaluation because the data set comprises a similar time span. As a result and after data cleansing (removal of service bookings and corrupt entries) n= 652.407 bookings that occurred in Munich and Berlin from November 2011 to October 2012 are analyzed. For each of the bookings there is reliable data on the vehicle ID, start and end time and date, start and end GPS-coordinates, trip type (private, business, service), customer ID, and reservation type (website, mobile, spontaneous).

Structural data for cities stems from infas GEOdaten. [98] This provider was chosen for having the most comprehensive data base in Germany even though not every potentially interesting factor is available. The data is supplied on ”Wohnquartier” (KGS22) level. These areas/tracts/segments are based on electoral districts and comprise roughly 500 households. For Berlin, this equates to 3886 tracts, for Munich to 1685 tracts, and for Düsseldorf to 593 tracts. This fine scale is needed to show the variance of data within a city as well as to ensure a sufficiently big sample size.

For the determination of dependent and independent variables only tracts with more than 50 bookings (equals to one booking per week) are considered to eliminate outliers, effects of the predefined business areas, parks, lakes, etc. in the data. Through this measure, 2568 tracts for Berlin and 877 for Munich are eliminated in which only 15.305 or 2.36% of all bookings occurred. For further analysis, such as in the modeling of the business area in subsection 4.3.1, the whole dataset is used.

3.3.3 Finding and Describing Suitable Dependent Variables as Measures of Success

Number of Customers

Overall, the number of active customers (a customer who drove at least once within the examined 12 months) in both cities (see figure 3.5) is constantly growing in the examined period while Berlin shows a higher growth rate.

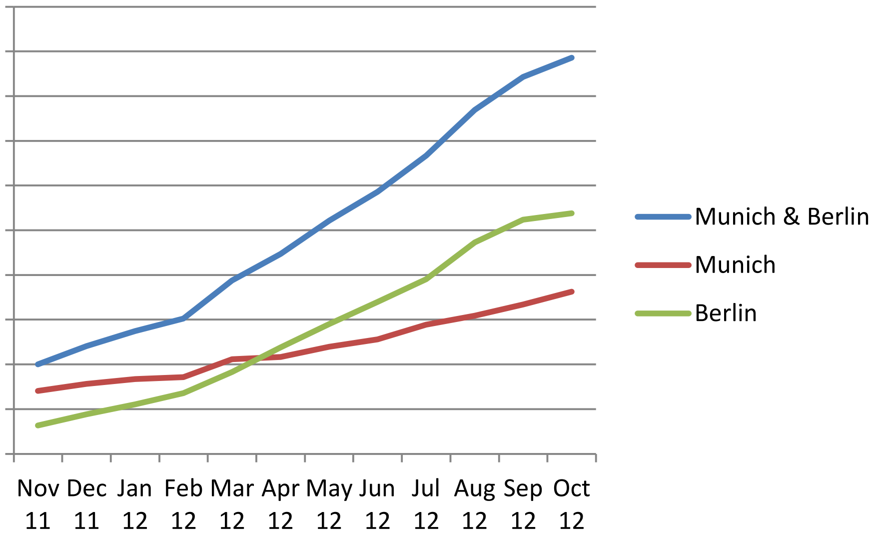


Figure 3.5: Number of Active Customers over Time per City in the Data Collection Period

However, the absolute number of customers does not reveal customer behavior. Figure 3.6 shows that there is an uneven distribution of the number of customers compared to the number of bookings: only 10% of the most active users account for 53% of all bookings. This is equally true for both cities as well as for the duration of bookings (see figure 3.7). Considering this, the ten most active percent of active customers even account for 56% of the accumulated booking time.

In order to specify customer segments more clearly, a cluster analysis was performed. The chosen cluster method was a two-step cluster analysis, which, according to Schendera [195] and Denk [64] suited best compared to hierarchical methods due to the large amount of data. Cluster variables are regularity (in how many of the 12 studied months did the customer book), booking duration, and number of bookings. The number of clusters is determined by the Bayesian information criterion (BIC), returning three clusters which are described in table 3.1 as well as they are marked in figure 3.6 and figure 3.7.

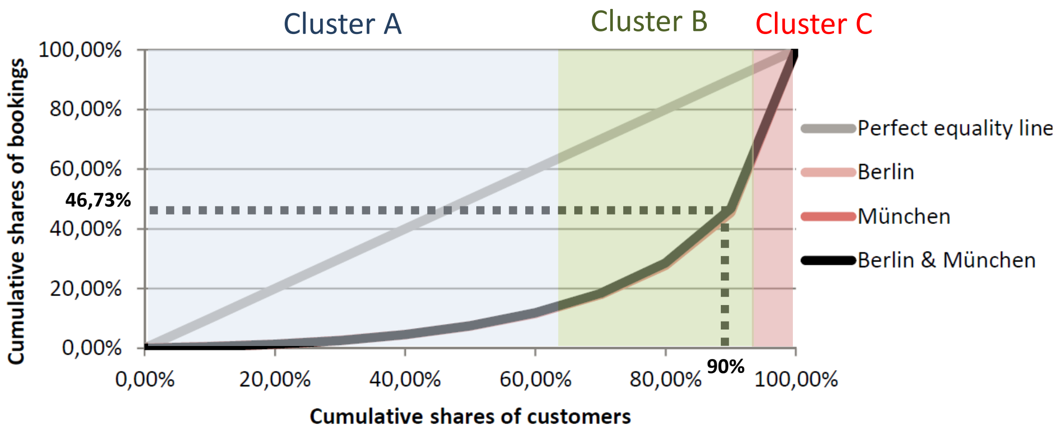


Figure 3.6: Lorenz Curve for the Determination of Customer Segments: Number of Customers over Number of Bookings

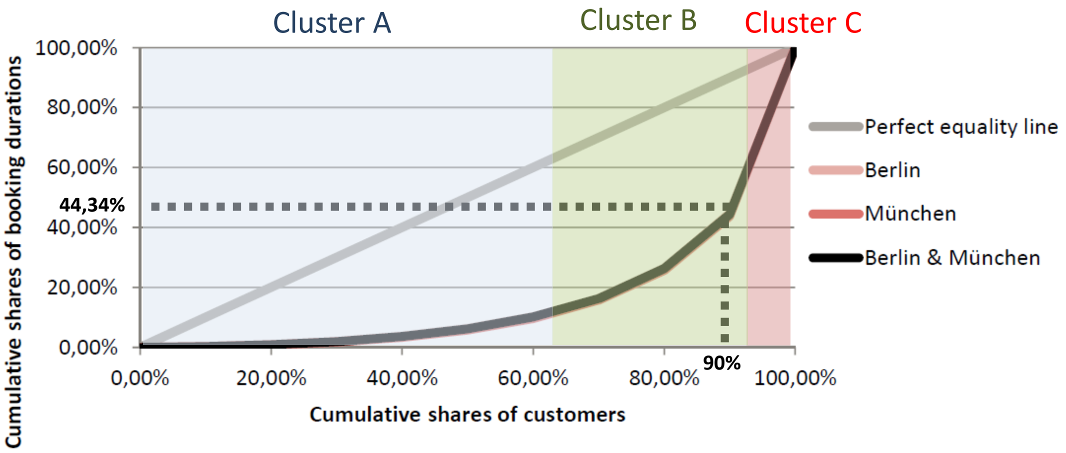


Figure 3.7: Lorenz Curve for the Determination of Customer Segments: Number of Customers over Duration of Bookings

Table 3.2 gives a description on the identified clusters and number and duration of bookings appear as most distinguishing characteristics between clusters. Regularity, showing in how many of the 12 studied months the system was used, differs as well but the spread is considerable. However, for customer segmentation further studies are needed to characterize customer segments as existing data is not sufficient because it does not contain sociodemographics. Nevertheless, analysis shows that customers behave very different and usage varies massively. Therefore, analyzing customers and specifically heavy users can be of great interest.

In order to locate customers in the city, their ”address” was defined as the spot or local area, where customers book most often because real data was not available. The heat map of customer addresses per inhabitant reveals for that customer density (based

Cluster	% of customers	% of total time	% of total bookings
A	63.7%	17.0%	16.5%
B	28.6%	36.5%	38.7%
C	7.7%	46.5%	44.8%

Table 3.1: Cluster Analysis of Customers

Cluster A	**Mean**	**Median**	**Mode**	**Min.**	**Max.**
Number of bookings	5.1	3	1	1	54
Duration of bookings	192.9	106	26	1	3161
No of months used	1.9	2	1	1	4
Cluster B	**Mean**	**Median**	**Mode**	**Min.**	**Max.**
Number of bookings	26.5	22	13	2	98
Duration of bookings	917.6	721	379	52	4,447
No of months used	6.1	6	5	1	12
Cluster C	**Mean**	**Median**	**Mode**	**Min.**	**Max.**
Number of bookings	114.1	95	93	7	656
Duration of bookings	4,350	3,516	2,908	563	32,489
No of months used	9.3	10	12	1	12

Table 3.2: Description of Relevant Identified Segments (Clusters)

on total population) is only slightly uneven distributed in Berlin and no ”customer hot spots” could be identified. However, some areas (e.g. Prenzlauer Berg) already have a considerable market penetration of up to 10% (see figure 3.8).

In Munich however, there are few single areas (e.g. Maxvorstadt) where a considerable market penetration is reached (up to 81% in one segment). These are exceptions however, and the overall geographical distribution is relatively even as well. For this reason, an overall customer density does not appear as powerful dependent variable for success and since heavy users (cluster c customers) account for almost half the booking duration and count, their spatial distribution might be a better indicator. Analysis shows however, that there are relatively few cluster c customers and their spatial distribution is again relatively even. This might lead to wrong conclusions if single customers are represented by data that is an average for an area with 500 households. Again, market research based on customer surveys/ interviews could close this knowledge gap.

The representativity of the structural city data must be ensured however, since tract

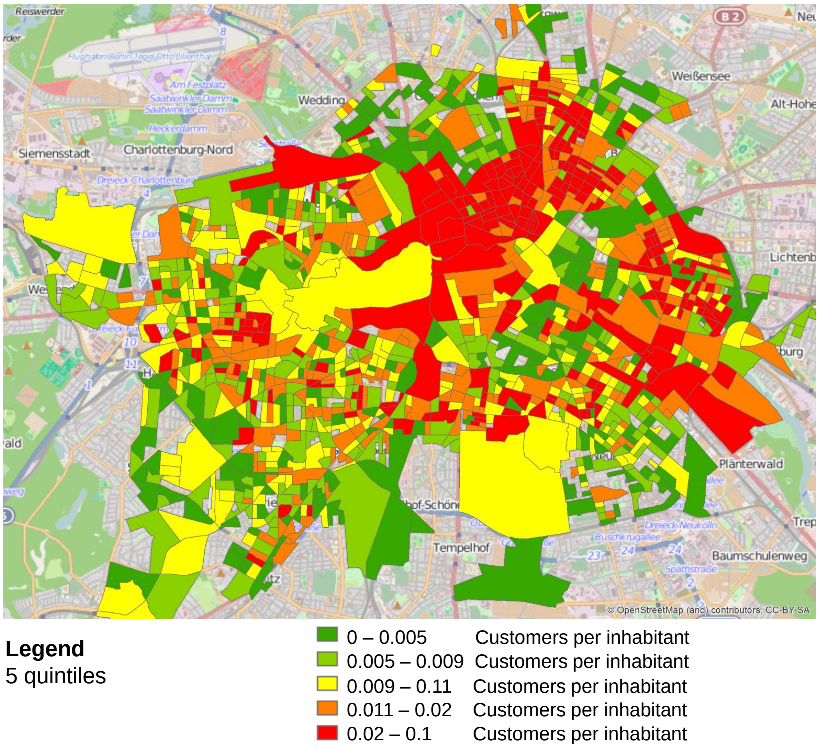


Figure 3.8: Customer Addresses: Customers per Inhabitant - Berlin

data is connected to the local inhabitants. To ensure this, it is analyzed if there is a relationship between booking and living. Under the assumption that customers are willing to walk up to 5min or 500m [154, 235] to a car and also from a car to their home (due to parking), data shows that 61.1% of all bookings either start or end close (<0.5km) to a customers' home address. This shows that the home address is very relevant, even if it only accounts for 61% of bookings. Interestingly, heavy users (cluster C) show an even higher home involvement, indicating that these users see carsharing as a replacement for car ownership (see figure 3.9).

Number of Bookings

The total number of bookings over time shows a steady increase (see figure 3.10) as the business is fairly new and expanding for which reason a month by month comparison could lead to wrong conclusions. Again, Berlin shows a higher growth rate which can be explained by a bigger size of Berlin, faster customer growing rates, and a better booking per member ratio. It must be noted that the decrease in bookings in Berlin in 10/2012 is due to missing data in the analyzed data-set and not because of a decrease in bookings in reality.

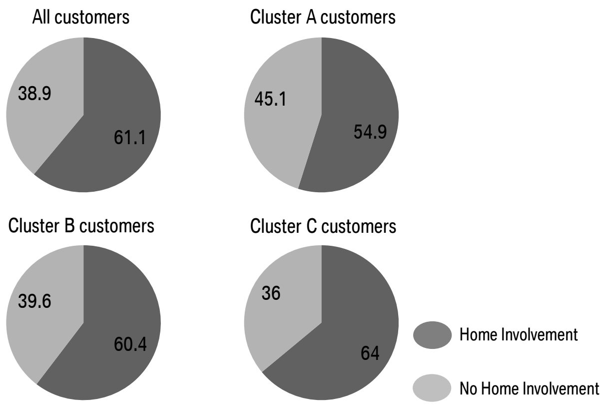


Figure 3.9: Relationship of Booking and Living: Involvement of the Home Address (Distance <0.5km to Booking End or Start)

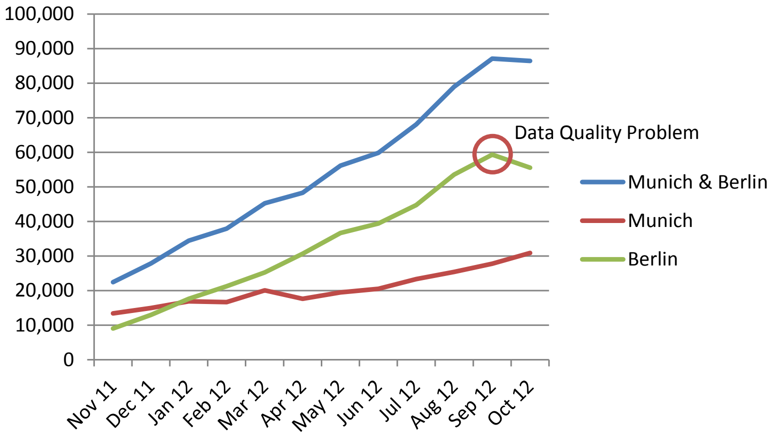


Figure 3.10: Bookings Over Time

When locating bookings, either the start or the end of a booking session can be chosen. Figure 3.11 shows that there are only little differences between start- and end-locations of bookings. Normally the end of one booking is the start of the next; however, fleet management sometimes relocates vehicles which is the reason for the little variety. For further analysis, this difference can be neglected and locations where booking sessions start (=demand) also represents destinations.

Knowing that booking start- and end-locations are mostly the same is very important since figure 3.12 reveals that most bookings are one-way, which means a customer drives from A to B. On the other hand, a round trip (A to A) is characterized by <1km beeline distance of start and end point and a booking time exceeding 10min so that very short trips are not considered as round trips.

Looking at the spatial distribution of bookings, a number of hot-spots appear as prevalent, e.g. the best 10% of tracts account for 39% of all bookings as can be seen in

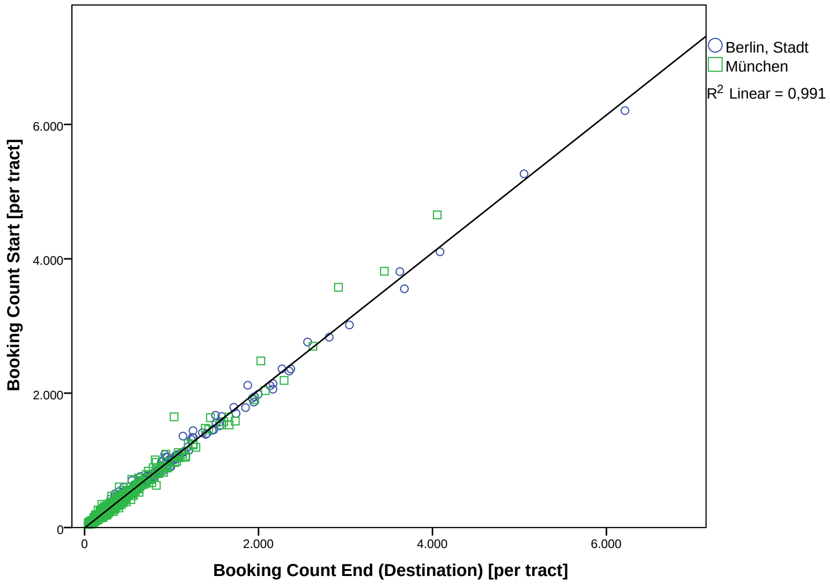


Figure 3.11: Difference of Counts of Booking Start and End Points

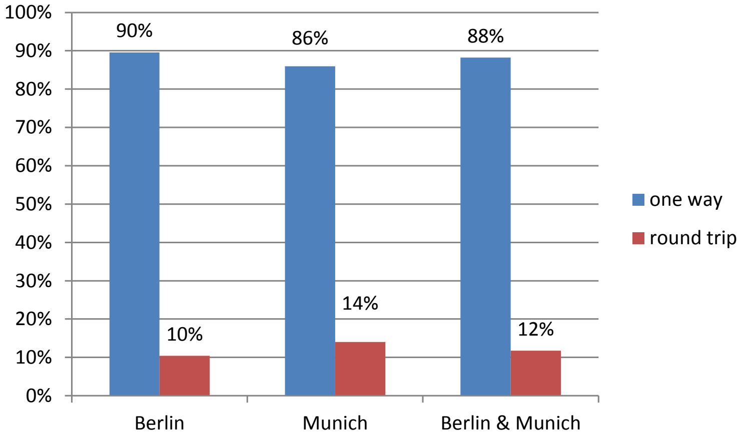


Figure 3.12: Driving Profiles (One Way and Round Trips)

figure 3.13. The uneven distribution of tracts and number of bookings is equal in both cities and suggests that there are more successful areas and less successful areas in both cities. The unevenly distributed booking density of both cities can also be depicted by heat-maps, see figure 3.14 and 3.15, showing the distribution of bookings per km^2.

Duration of Bookings

The duration of bookings can be geographically located by assigning each start point the duration of the booking. Normalized, this leads to a booking duration density which is the sum of booking minutes initiated in a segment divided by its area. There are some areas that cause an over-proportionally long booking duration, but overall

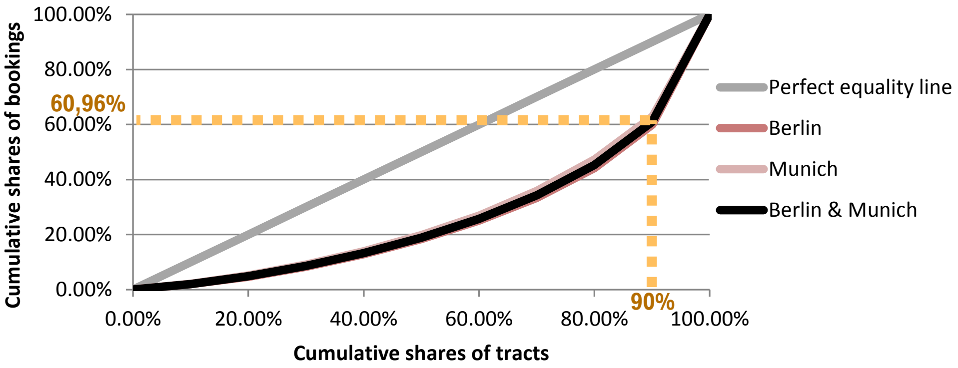


Figure 3.13: Lorenz Curve for the Determination of the Spatial Distribution of Bookings: Number of Bookings over Number of Tracts

analysis in figure 3.16 shows that there is a strong link between booking duration and number of bookings, for which reason they need not be considered separately. Also, both cities behave similarly and the slight difference between Munich and Berlin shows the lower booking frequency but longer booking duration in Munich.

3.3.4 Analysis Results

To sum up the previous three subsections, the number of customers or their density appears not to be a powerful dependent variable to represent success since customers live across the city (or even somewhere else) and are highly segmented. On the upside, bookings are significantly connected to a customer's address so that structural data for an area can be applied to the bookings that occur in it. Looking at the number of bookings and booking durations revealed that they are highly correlated and can be used interchangeably.

Bookings are unevenly spatially distributed and in both cities a number of hotspots are prevalent. This suggests that there are differently successful areas in both cities making booking density (related to the start of a trip) a powerful geographical indicator for success as it covers booking time as well as frequent destinations (end points). However, interchangeably and where it is more applicable, also booking time can be used as success indicator.

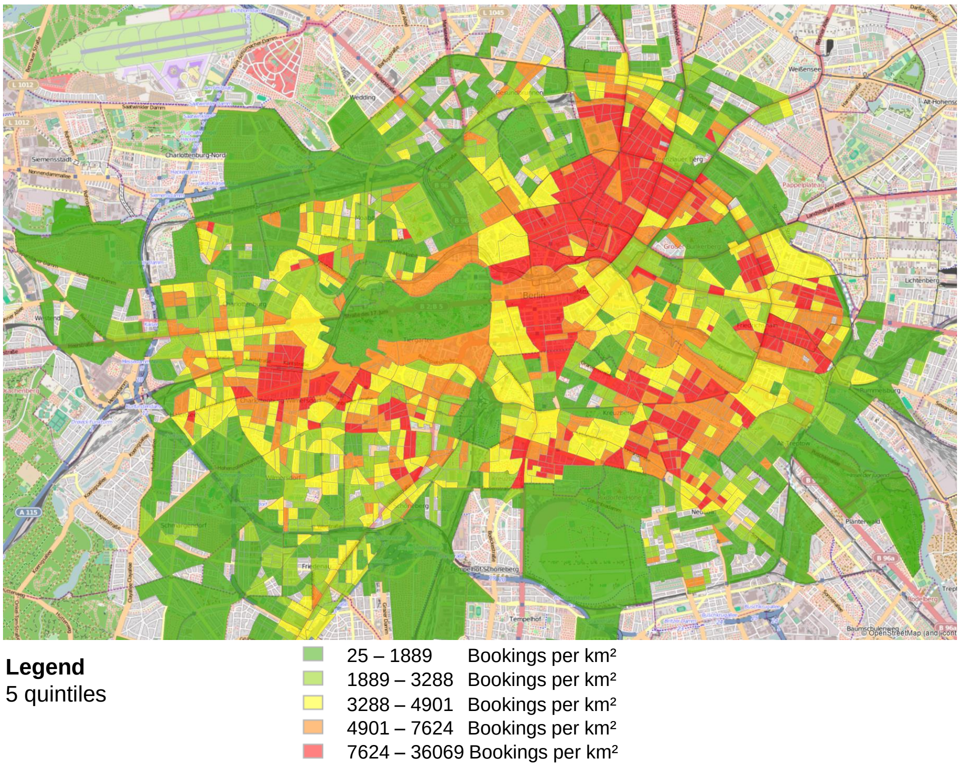


Figure 3.14: Booking Density Berlin (Bookings per km^2)

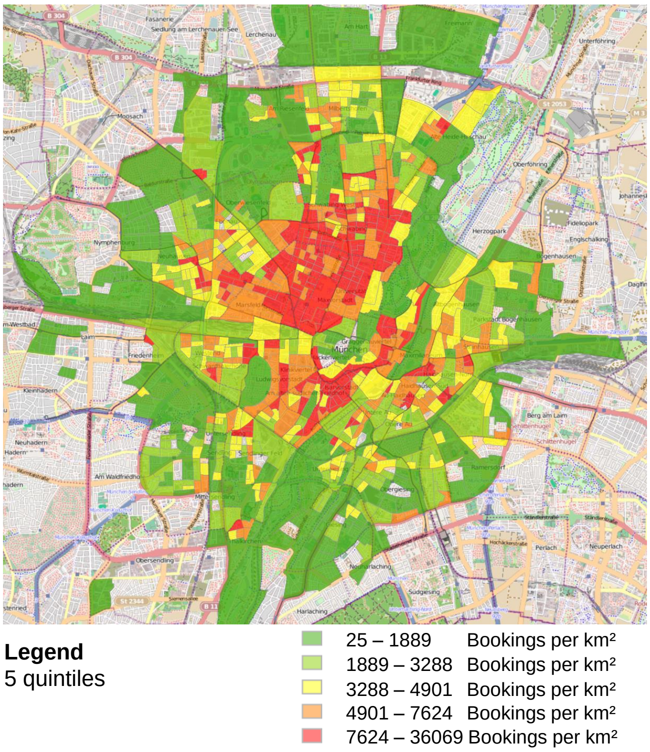


Figure 3.15: Booking Density Munich (Bookings per km^2)

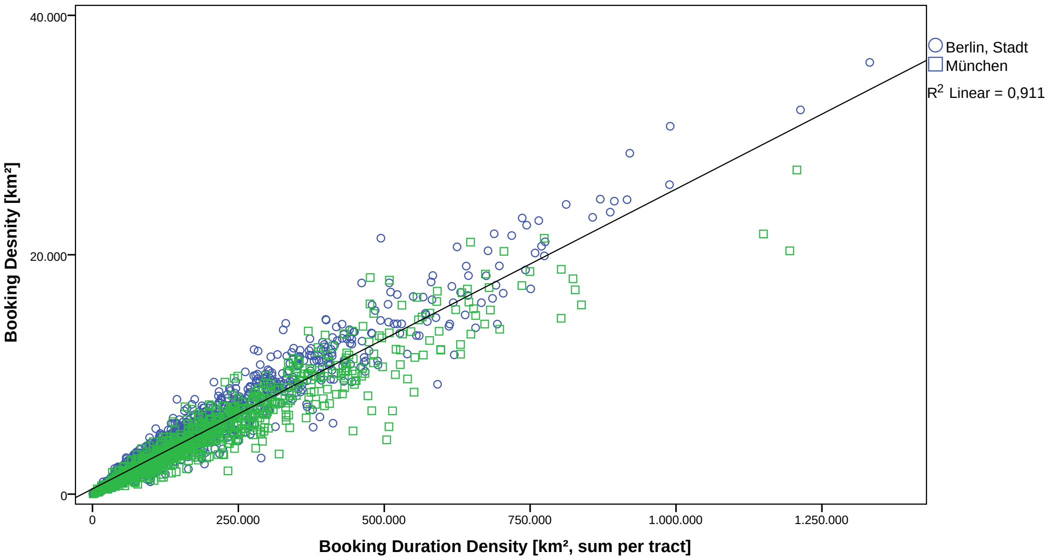


Figure 3.16: Scatterplot to Determine Relationship of Booking Duration and Number of Bookings within a Tract

3.4 What Influences Success?

3.4.1 Defining Success Factors

Following the definition of success in section 3.3.1, a success factor in this research is a factor that influences or determines adoption. According to Rogers [186], five factors influence adoption and its rate:

- Attributes of an innovation, as perceived by potential adopters
- The number of people involved in making an adoption decision
- Communication channels, because if awareness is only spread through interpersonal channels it slows down diffusion
- The nature of the social system, which determines communication and perceptions
- The extent of promotion efforts, which raises awareness effectively during the early stages of adoption

Taking Rogers work into consideration, Wejnert and Faiers extend the approach [257, 77] and and make it less communication focused and therefore more comprehensive. Here, variables influencing the decision to adopt an innovation are grouped into three major components: environmental context, characteristics of adopters, and attributes of the innovation. Figure 3.17 gives an overview on the three determinants discussed in this section, their interrelatedness and their underlying variables.

Environmental Context

Innovations are not independent from their environmental context. Their successful transfer depends on their fit with the new environments which they enter during diffusion. Five environmental context variables are proposed:

(1) *Geographical settings* affect adoption by influencing the applicability of the innovation to the existing infrastructures as innovations can be adopted only when they are suitable to the environment of the adopter. Additionally, effects of geographical proximity play a role since innovations spread automatically between individual actors who are in close geographical contiguity.

(2) Variables of *societal culture* such as belief systems (values, norms, language, religion, and ideologies), cultural traditionalism, cultural homogeneity, and socialization of individual actors influence adoption of innovations.

(3) The impact of *political conditions* on adoption primarily concern political systems, along with the regulations and norms inherent in the legal systems that control actors' behaviors.

(4) Variables related to *global uniformity* include: First, institutionalization, the spread of rule-like behavioral models providing an implicit structure of incentives for the adoption of approved forms of practices; second, global technology, facilitated by the growth of multinational corporations; and third, world connectedness via modern communication systems or media effects. [257]

(5) *Existing competition* for an innovation influences adoption [97, 16] as it gives alternatives and fuels expectations. This variable is not an original part of many frameworks as it is similar to the ”relative advantage” an innovation must have to be adopted (see innovation attribute dimension below). However, since carsharing is a local product, mostly the existence and condition of local competition matters and is consequently treated as fifth variable within the environmental context.

Characteristics of Adopters

Rogers' [186] categorization of adopters shows that individual characteristics play an important role in adoption. Also marketing research covers this topic extensively as differences between consumers are of fundamental interest to marketers and many types of differences are listed. [67] Here, six sets of variables modulate the adoption of innovations:

(1) The *societal entity* of adopters is important because adoption processes are different for individual actors compared to collective actors such as organizations. In this work this can be factored out since the focus is on individual adoption only.

(2) The *familiarity with the innovation* is influential because people are naturally cautious in approaching novelty and therefore the rate of adoption of an innovation increases as its novelty decreases. Information obtained from close peers reduces novelty and increases familiarity with innovations. Information from media or experts has the same effect but to a lesser extent.

(3) *Status characteristics* of adopters refer to the prominence of an actor's relative position within a network. High-status members identify innovations and then spread them to lower-status members. This can be the opposite when innovations are controversial in nature because lower-status members are less fearful of losing popularity by nonconformist behavior.

(4) *Socioeconomic characteristics* of the adopter influence adoption. Here, economic variables often account for more variance in adoption than sociodemographic variables or an actor's social position.

(5) The *relative position in social networks* determines adoption since timing of adoption typically depends on the interaction of social units in a process of communication. Interpersonal networks significantly impact adoption: Adoption by some actors has a cumulative effect on the adoption decisions of other actors in the social network.

(6) *Personal characteristics* of individual actors modulate adoption of innovations. Self-confidence, risk-taking propensity, and independence are suggested because they modulate the extent to which an individual adopts an innovation without waiting for the security of observing others. Personal characteristics, however, are modulated by societal culture. [257]

Attributes of the Innovation

Transforming the objective, measurable innovation attributes into innovation attributes as perceived by adopters is the subject of this category [93] and Rogers proposes five innovation attributes (first in [187]) that influence an individual's perception:

(1) *Relative Advantage* "is the degree to which an innovation is perceived as being better than the idea it supersedes". This might include economic factors (initial cost, cost of use, saving of time/effort), status aspects (social prestige, trend), and comfort (decrease in discomfort, immediacy of reward, low risk). [186]

(2) *Compatibility* "is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters." An innovation can be compatible/incompatible with sociocultural values and beliefs (cultural values, local habits, naming of an innovation), previous adoptions and ideas (past experience and behavior, existing technology), and client needs for the innovation (fulfillment of felt and conscious needs). [186]

(3) *Complexity* is defined as "the degree to which an innovation is perceived as relatively difficult to understand and use." Subdimensions could be the simplicity of understanding and using the innovation as well as availability of support. [186]

(4) *Trialability* is defined as "the degree to which an innovation may be experimented with on a limited basis" [186] Trialability should refer to the physical dimension, the interface dimension, and the informational dimension. [3]

(5) *Observability* is defined as "the degree to which the results of an innovation are

visible to others". This relates to the tangible aspect as well as the informational aspect of an innovation. [186]

In general, the high value of innovation attributes is accounted for by many disciplines. For example, this comprises marketing, [157] organizational theory, [263] and psychology. [81, 4] Especially the domain of information technology researches this area under the label of information systems implementation research [133] and more recently, technology acceptance modeling (TAM). [63, 246] TAMs were constantly modified in the last two decades [53] but are only proven in an IT-context and adoption determinants are similar to attributes which are proposed by Rogers. [3]

Consequently, Rogers' five attributes have been widely discussed, adapted and modified by many scholars over the last decades (see [155, 62, 112, 239, 229, 248, 233, 3, 252] but overall, after more than 40 years his proposed attributes still appear very relevant - also for this dissertation.

To sum up, three determinants of adoption or success factor "categories" were discussed: environmental context, characteristics of adopters and attributes of the innovation. This theory acts as a good foundation for the determination of success factors for carsharing with and without electric vehicles.

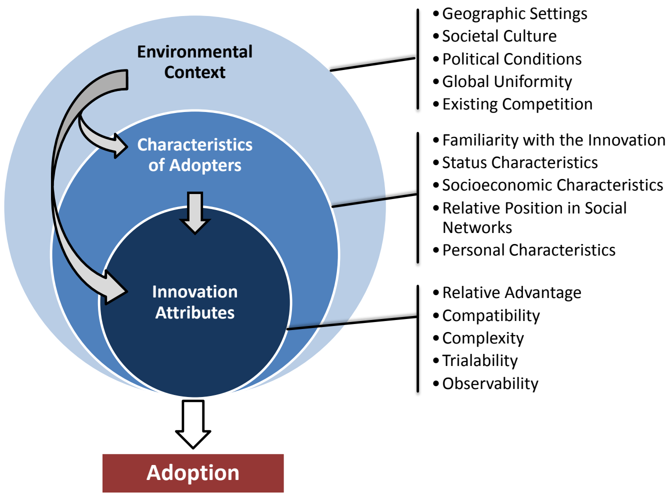


Figure 3.17: Determinants of Adoption and their Underlying Variables as Success Factors

3.4.2 Approach and Data Base

In this dissertation, success factors are determined independently from other research efforts since previous research (see chapter 2.4) was concerned with station-based carsharing. Naturally, there will be overlaps to already determined factors, but chances are that there might be new aspects for this new concept that have not been considered before, justifying the need for this analysis. The overall analysis approach for the determination of success factors (independent variables) consists of three main steps which are depicted in figure 3.18.

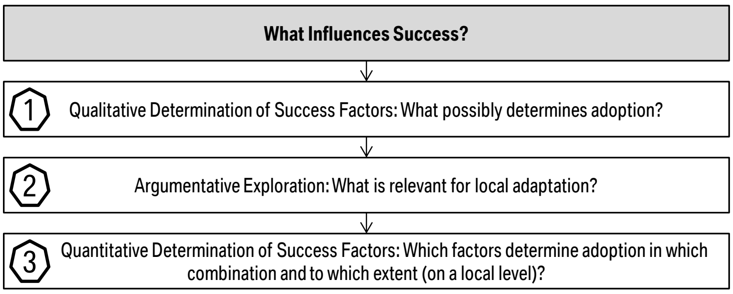


Figure 3.18: Overall Analysis Approach for the Determination of Success Factors

In a first step, it has to be determined what the specific determinants for the adoption of carsharing are. When choosing the sources of evidence the research strategy does not necessarily determine sources and moreover, the usefulness for the research, not the absolute strength of a source is crucial. [65] For this part of the work, interviews seem especially useful due to the innovative character of free-floating carsharing. Semi-structured interviews, with predominant questions that can be modified during the interview, [185] might be the most important way to conduct a research interview because of its flexibility balanced by structure, and the quality of the data obtained. [101] Additionally, applying open-ended questions allows the respondent complete freedom to reply and to take up a direction in the response. [121] Furthermore, benefits from data can be maximized by using multiple sources of evidence [262] and data triangulation is achieved by interviewing stakeholders with different perspectives: customers, experts, and companies. This triangulation of stakeholders implicates the fact of viewing something from different perspectives, just like in trigonometry where an exact location of a point can be found if it is viewed from two other known positions. [65] Because this innovation is only currently emerging, stakeholders of conventional carsharing and/or electromobility are also interviewed as they are likely to be future stakeholders of (E-)carsharing.

As a result, the study relies on 34 interviews in total, conducted in Germany, Netherlands, UK, France, Switzerland, Austria, and USA in person and over the phone:

- 10 interviews with carsharing-providers of which six have experience with BEVs
- 3 interviews with manufacturers of BEVs
- 9 interviews with customers of electromobility and carsharing
- 12 interviews with other stakeholders from governments, suppliers, infrastructure providers, universities or industry-experts

These interviews were also used by the author for his dissertation submitted for the degree of Master of Philosophy in Industrial Systems, Manufacturing and Management at the University of Cambridge. This work holds the title ”Business Models for the Diffusion of Innovation: Understanding the Adoption of Carsharing with Electric Vehicles” [206] and the gathered data was used within a case study for a different research question of ”how can business models be designed to support the adoption of innovations?”. Further, a summary was presented at the Conference on Future Automotive Technology 2013 [207].

Just as explained in section 3.2, following the interviews, data was recorded, stored, analyzed and matched to theory and the aim of this research. This is depicted in figure 3.3.

Having determined the broad range of hypothetical adoption determinants for carsharing, step two is to explore them argumentatively and qualitatively whether they are relevant for local adaption or not. Since the input of step one is based on broad and universally valid diffusion of innovation theory, this step ensures research specific focus and reduces complexity in order to enable quantitative analysis in step three. For this and for step two the same booking and structural data base as in section 3.3 was used, where the data was also described in detail.

Step 3 uses this data and the input from step 1 and 2 to perform a regression analysis. The reasons for choosing this method of analysis are multifarious. Most importantly, there is a need for a multivariate analysis method because independent variables are possibly interrelated. Also, factors with the biggest impact on success on a univariate basis might be different from a multivariate perspective which is closer to real world's complexity. According to Backhaus et al. multivariate analysis methods can be grouped in ”structure verifying” and ”structure discovering” methods. [14] Since step 1 is concerned with developing hypothesizes about possible relationships, in general, structure verifying methods should be applied in order to test these hypothesizes. Within the range of possible methods, the scales of measure regarding the dependent and independent variables are important. Since this research is concerned with metric scale levels rather than nominal scale levels, regression analysis and time series are possible methods that qualify. However, temporal and periodical relationships are not in focus for which reason regression analysis appears as most useful analysis method. It can be used to estimate relationships among variables, give prognoses on how the dependent variable changes when one of the independent variables changes, as well as it is possible to create predictions for future developments (ceteris paribus). [14] Furthermore, regression analysis can also be used to explain observed spatial patterns as it allows to model, examine, and explore spatial relationships. [204] To carry out a regression analysis, Sutherland and Bergin [232] propose five steps:

1. Create scatter plots between the dependent variable and all independent variables in order to note direction and strength of possible relationships (e.g. if there is any relationship at all and if it is linear to fit in methodological assumptions of regression analysis)
2. Run OLS (ordinary least squares) regression
3. Check if the overall model is significant
4. Check if the coefficients are significant
5. Check which variable is most important and how much variation the model explains

Subsection 3.4.5, where the regression analysis is performed, is designed according to these five steps and detailed statistical explanations will be given where applied.

3.4.3 Qualitative Determination of Success Factors

In order to get a comprehensive overview on what possible success factors (adoption determinants) for free-floating carsharing might be, 34 interviews were carried out and as a result 152 hypothetical factors appeared. These factors are presented as hypothesizes organized by their theoretical roots in table 3.3.

Again, to keep this work clear and comprehensible, the detailed analysis report with explanations and considerations of experts' is outlined in Appendix D.

No	Category	Success Factor
Environmental Context		
1	Geographical Settings	population density
2	Geographical Settings	absolute poplation
3	Geographical Settings	mixed main movements within an area
4, 5, 6	Geographical Settings	quality of public transportation, quality of cycling infrastructure, walkability (=intermodal infrastructure)
7	Geographical Settings	topography
8	Geographical Settings	parking cost
9	Geographical Settings	parking availability
10	Geographical Settings	average vehicle travel distance
11	Geographical Settings	traffic density
12	Geographical Settings	tourism
13	Geographical Settings	charging infrastructure
14	Geographical Settings	climate conditions
15	Societal Culture	status of ownership
16	Societal Culture	collectivism
17	Societal Culture	status of cars
18	Societal Culture	status of public transportation
19	Societal Culture	ecological awareness
20	Societal Culture	ecological friendliness
21	Societal Culture	openness
22	Societal Culture	liberalism
23	Societal Culture	status of premium cars
24	Societal Culture	economic development
25	Societal Culture	living quality
26	Societal Culture	uncertainty avoidance
27	Political Conditions	private car ownership is disincentivised
28	Political Conditions	designated parking in new houses
29	Political Conditions	dedicated on-street parking
30	Political Conditions	availability of public space
31	Political Conditions	preferred parking
32	Political Conditions	use of certain lanes
33	Political Conditions	access to restricted areas
34	Political Conditions	grants
35	Political Conditions	tax breaks
36	Political Conditions	free charging
37	Political Conditions	exemption from congestion charges
38	Political Conditions	purchase rebate
39	Political Conditions	standardisation
40	Political Conditions	promotion
41	Global Uniformity	oil price
42	Global Uniformity	preference change
43	Global Uniformity	sustainability
44	Global Uniformity	urbanisation
45	Global Uniformity	connectivity
46	Global Uniformity	convenience
47	Global Uniformity	individualisation
48	Global Uniformity	increased travelling
49	Competition	other car sharing companies
50	Competition	cost of alternatives
51	Competition	cost of car rental
52	Competition	cost of taxi
53	Competition	cost of biking
54	Competition	cost of sharing of private cars
55	Competition	cost of peer-to-peer car sharing
56	Competition	cost of carpooling
57	Competition	cost of public transportation
58	Competition	cost of private cars
59	Available Technology	charging time
60	Available Technology	easy charging process
61	Available Technology	cost of charging
62	Available Technology	availability of parking information
63	Available Technology	transparency about IT
64	Available Technology	reliability of the IT technology
65	Available Technology	vehicle range
66	Available Technology	vehicle winter performance
67	Available Technology	vehicle functionality
68	Available Technology	vehicle reliability
69	Available Technology	vehicle cost
Adopter Characterisitcs		
70	Familiarity w/ innovation	Familiarity with the technology
71	Familiarity w/ innovation	Familiarity with other users
72	Status Characteristics	high status
73	Socioeconomic Charac.	high education
74	Socioeconomic Charac.	mixed income
75	Socioeconomic Charac.	driving license
76	Socioeconomic Charac.	family size
77	Socioeconomic Charac.	age
78	Socioeconomic Charac.	gender
79	Personal Characteristics	technology affine
80, 81, 82	Personal Characteristics	networked, communicative, open
83	Personal Characteristics	ecologically aware
84	Personal Characteristics	risk taking
85	Personal Characteristics	confident
86	Personal Characteristics	independent
87	Personal Characteristics	rational
Innovtion Attributes		
88	Relative Advantage	possibility to use cars
89	Relative Advantage	saving of money
90	Relative Advantage	comfort
91	Relative Advantage	convenience
92	Relative Advantage	saving of time
93	Relative Advantage	no ownership duties
94	Relative Advantage	flexible
95	Relative Advantage	spontaneous
96	Relative Advantage	independent
97	Relative Advantage	variety of cars
98	Relative Advantage	image
99	Relative Advantage	benefit from regulatory advantages
100	Relative Advantage	ecological adavantages
101	Compatibility	modern cars
102	Compatibility	fun cars
103	Compatibility	well-equipped cars
104	Compatibility	brand of the cars
105	Compatibility	cars must be charged with renewables
106	Compatibility	well maintained cars
107	Compatibility	no commitment
108	Compatibility	possibility to plan
109	Compatibility	spontaneity
110	Compatibility	flexibility
111	Compatibility	community membership
112	Compatibility	BEVs cannot be worse than ICEs
113	Compatibility	multimodal integration
114	Compatibility	phone compatibility
115	Compatibility	payment methods
116	Compatibility	availability
117	Compatibility	reliable technology
118	Compatibility	reliable service
119	Compatibility	charged cars
120	Compatibility	reliable information about range
121	Compatibility	big operating areas
122	Compatibility	attractive long-term pricing
123	Compatibility	global offer in many cities
124	Compatibility	mix of electric & conventional cars
125	Compatibility	reserved parking spaces
126	Compatibility	information on parking
127	Compatibility	free looking for parking spaces
128	Compatibility	no fixed stations
129	Compatibility	one-way trips
130	Compatibility	cleanliness
131	Compatibility	support quality
132	Complexity	ease of use
133	Complexity	simple handling
134	Complexity	simple charging
135	Complexity	training
136	Complexity	transparent price structure
137	Complexity	transp. limits of the operating area
138	Complexity	transparent parking rules
139	Complexity	transp. liability in case of damage
140	Complexity	transparent range
141	Complexity	transparent communication
142	Complexity	easy registration process
143	Trialability	curiousity about electric vehicles
144	Trialability	possibility to test a variety of cars
145	Trialability	registration cost as hurdle
146	Trialability	trial sessions
147	Trialability	introdction sessions
148	Observability	on-street charging stations
149	Observability	visible location of stations
150	Observability	subtle appearance
151	Observability	awareness of the concept
152	Observability	understanding of the concept

Table 3.3: Qualitatively Determined Success Factors

3.4.4 Argumentative Exploration

Section 3.4.3 shows that the adoption of free-floating carsharing depends on a vast variety of factors. Some of these factors were previously studied for traditional station-based carsharing whilst others are new. In any case, their general validity as well as their particular validity for free-floating carsharing must be tested. Moreover, they are often not simply positively/negatively correlated to adoption. For example, quality of public transportation must be good so that people give up their private car, use public transportation, and complement it with carsharing. If the service is too good however, people can solely rely on it and carsharing might become obsolete because it profits from filling gaps in public transportation systems. The same is true for many other factors such as population density, income etc. The quantitative analysis in section 3.4.5 will reveal the direction and strength of the suspected relationships of this section. Before however, and in order to focus on the research aim – the local adaption of offers – all 152 success factors must be explored in terms of their influence to local adaptation. Hence, the question this section revolves around is: To which factors must be locally adapted? In order to answer this question, two filters are applied:

Filter 1 is the question whether a factor varies between locations or not. If an aspect of carsharing has to be locally adapted to a success factor, this factor must consequently vary in different locations. For example, the compatibility to cellphones is important for customers but it is a success factor that is inherent to the concept and does not vary between locations.

Filter 2 is the question whether it is possible to measure a factor in small territorial units. This is important since the system shall not only be adapted *to* a city, but also needs to be adapted *within* a city. For example, different climate conditions of two cities might influence success, but once a city is chosen, the offer cannot be adapted to a city-wide factor such as climate.

Lastly, all factors that passed both filters are checked for data availability. For example, parking availability is a factor that differs from city to city and also from location to location within a city. Furthermore, it is a potentially important factor for the success of carsharing but unfortunately, no data is available.

For clarity purposes, the detailed execution of the argumentative exploration is depicted in tabular form in Appendix E. As a result, 27 success factors remained to which carsharing systems must potentially be adapted to and for which data is available. This approach is also depicted in figure 3.19.

However, not every factor can be directly measured. ”Mixed main movements

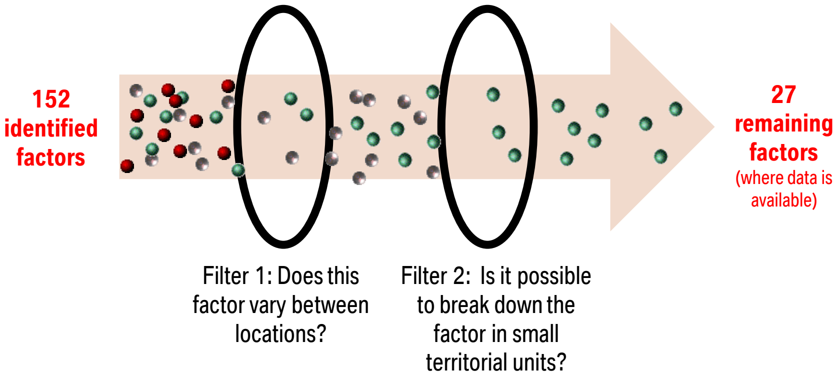


Figure 3.19: Argumentative Exploration - To which Factors Must be Locally Adapted?

within an area" for example are hard to indicate with a single number. As a consequence, indicators must be found that are content-related and measurable. For this example, company density, centrality, and rent are good indicators: A high number of companies indicates business or leisure (restaurants, clubs, etc. are included) trips, a high centrality similarly indicates an inflow of purchasing power, and a high rent indicates high demand for living which is mostly found in attractive areas with mixed use (center, sub-centers). In other cases, such as with population density, the factor can be measured directly and the indicator is equal to the success factor. The allocation of indicators to success factors revealed that the remaining 27 success factors of the previous filtering can be represented through 39 indicators. These 39 indicators as well as the detailed execution is carried out in tabular form for clarity purposes and can again be found in Appendix E.

In summary, the argumentative exploration in this section reduced 152 general success factors for free-floating carsharing to 27 success factors to which the system must be potentially adapted to. In order to find out whether there is a measurable relationship to success, these 27 factors are represented by 39 measurable indicators which will be quantitatively analyzed in the next section.

3.4.5 Quantitative Determination of Success Factors

In this subsection, the argumentatively selected factors are explored quantitatively whether there is a measurable relation to success or not. After having determined dependent (section 3.3) and independent variables (section 3.4.3 and 3.4.4) this subsection applies a regression analysis. To do so, scatter plots between the dependent and all independent variables (represented through the 39 indicators) have to be created as the direction and strength of possible relationships must be noted in order to verify that the hypothetical relationships are true and that methodological prerequisites of regression analysis are met (e.g. linearity). [232]

When examining these scatterplots – which can be found in Appendix F – and the respective coefficient of determination R^2 (which is in this case of a two-dimensional regression also the squared Pearson product-moment correlation coefficient), only 13 notable relationships are found. These relationships are noted between booking density as dependent variable and the following independent variables:

1. population density ($R^2 = 0.1104$)
2. company density ($R^2 = 0.2004$)
3. rent index ($R^2 = 0.1437$)
4. distance to an ICE train station ($R^2 = 0.1123$)
5. distance to the city center (town hall) ($R^2 = 0.1578$)
6. restaurant and hotel density ($R^2 = 0.1782$)
7. natural gas vehicle affinity index ($R^2 = 0.0701$)
8. lifestyle (type down-to-earth) ($R^2 = 0.0462$)
9. lifestyle (type materialistic oriented) ($R^2 = 0.0531$)
10. car density ($R^2 = 0.1049$)
11. one person households ($R^2 = 0.05$)
12. UMTS affinity index ($R^2 = 0.1271$)
13. high-tech affinity index ($R^2 = 0.113$)

In this consideration, company density explains twenty percent of the variation in the response variable booking density. The remaining eighty percent can be attributed to unknown, one or more of the other twelve variables, or inherent variability. Consequently, no satisfactory single relationship was found. Furthermore, these thirteen indicators are highly correlated - mathematically and in terms of content. For example the distance to an ICE train station and to the city center (town hall) are strongly related as both analyzed cities have an ICE train station close to the city center. Similarly, a UMTS affine area is also high-tech affine and vice versa. To overcome this, a multiple regression must be applied which takes the interdependencies into account.

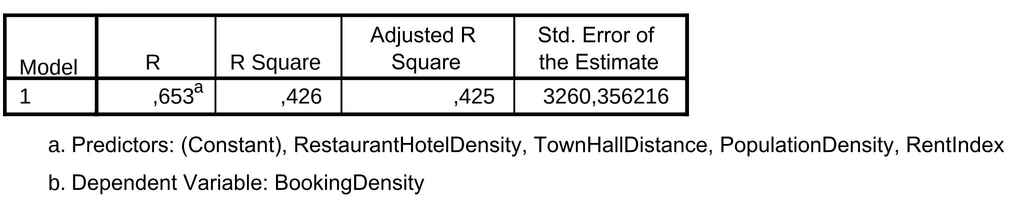
Since there are no more or less meaningful regression models, all potential combinations have to be tested and an exploratory regression is applied. Exploratory regression tries all possible combinations of explanatory variables to see which models pass all of the predefined ordinary least squares (OLS) diagnostic parameters. This method is similar to stepwise regression but rather than only looking for models with high R^2 values, exploratory regression looks for models that meet all of the requirements and assumptions of the OLS method. [74] The selection criteria were that the model must have one to five explanatory variables and an adjusted coefficient of determination (R^2) >0.3. The Adjusted R^2 ($\bar{R}^2$), is used in multiple regression to adjust R^2 downwards depending on the number of independent variables since simply adding more variables can raise R^2. It was further specified, that the coefficient's p-value (p-value $<0.05 \rightarrow$ coefficient is supposed to be statistically significant), the p-value of the F-statistic (p-value $<0.05 \rightarrow$ indicates overall model significance) and the VIF (Variance Inflation Factor) value (VIF $<7.5 \rightarrow$ explanatory variables are not redundant) meet the defined criteria.

As a result of this step, the following model appeared:

$$bd_i = x + pd_i + rd_i + thd_i + r_i \quad \forall i \tag{3.1}$$

- bd_i is the booking density of segment i
- pd_i is the population density of segment i
- rd_i is the restaurant and hotel density of segment i
- thd_i is the distance from segment i to the city center of the considered city
- r_i is the index of the rent of segment i

With an Adjusted R^2-value of 0.43 this model explains 43 percent of the variation in booking density through the independent variables which is very good. For field research and empirical data, already 20-30% rank as good result. [176] The remaining 57 percent can be attributed to randomness, unknown variables, or inherent variability. [196] Table 3.4 gives a model summary and also shows that the model has a standard error of estimate ($S_{y,x}$) of 3260.36, which is the square root of the mean squared error, or MSE. [22]



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,653[a]	,426	,425	3260,356216

a. Predictors: (Constant), RestaurantHotelDensity, TownHallDistance, PopulationDensity, RentIndex

b. Dependent Variable: BookingDensity

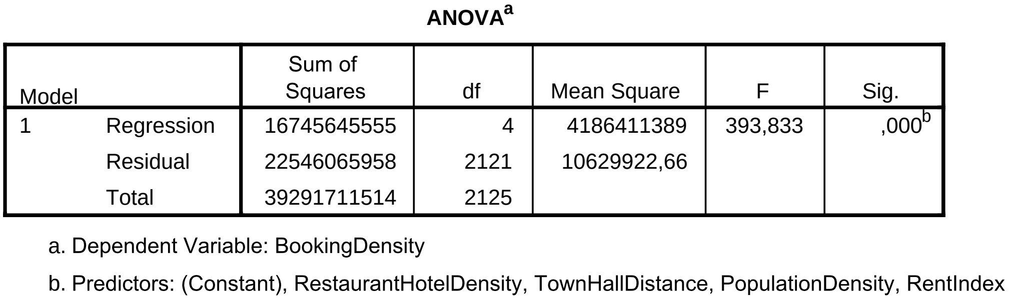
Table 3.4: Model Summary

Table 3.6 shows the ANOVA (Analysis Of Variance) table for the regression. There are two sums of squares - the regression and residual (or error) sums of squares. The variance of the residuals (or errors) is the value of the mean square error or MSE - here it is 10,629,922.658. Compared to the variance of booking density of 18,490,217.18 (see descriptive statistics of booking density in table 3.5), scattering is reduced by the factor 1.74.

	N	**Min.**	**Max.**	**Mean**	**Std. Deviation**	**Variance**
Booking Density	2126	25.01	36,069.05	5,177.61	4,300.03	18,490,217.18

Table 3.5: Descriptive Statistics

The ANOVA table (3.6) also shows the F test. Here, the hypothesis is tested, that the independent variables show no relationship to booking density. For this model, the value of the F test is F(4, 2121) = 393.833 and the table shows that this is significant (p <.001) and it can be determined that the model provides a significantly better prediction than the mean value. Hence, the overall model is significant [232] and booking density is related to population density, rent index, town hall (city center) distance, and restaurant and hotel density.



ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16745645555	4	4186411389	393,833	,000[b]
	Residual	22546065958	2121	10629922,66		
	Total	39291711514	2125			

a. Dependent Variable: BookingDensity

b. Predictors: (Constant), RestaurantHotelDensity, TownHallDistance, PopulationDensity, RentIndex

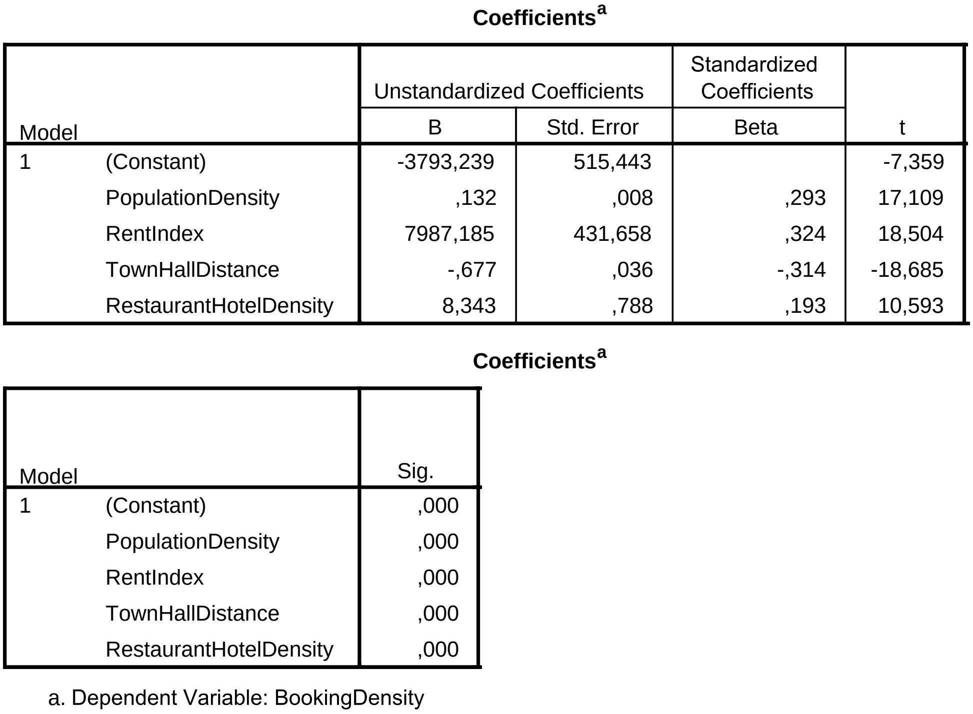
Table 3.6: ANOVA (Analysis Of Variance) Table

Table 3.7 gives information about the coefficients of the model. With this information the unstandardized regression model appears as:

$$bd_i = -3793.239 + 0.132 pd_i + 8.343 rd_i - 0.677 thd_i + 7987.185 r_i \quad \forall i \tag{3.2}$$

The unstandardized coefficients or slopes can be interpreted the following way: One meter increase in distance from the town hall reduces booking density by 0.677

bookings per square kilometer. The standardized or beta coefficients tell that rent index is the most powerful independent variable in this multivariate analysis, followed by town hall distance, population density, and lastly restaurant and hotel density.



Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t
1	(Constant)	-3793,239	515,443		-7,359
	PopulationDensity	,132	,008	,293	17,109
	RentIndex	7987,185	431,658	,324	18,504
	TownHallDistance	-,677	,036	-,314	-18,685
	RestaurantHotelDensity	8,343	,788	,193	10,593

Coefficients[a]

Model		Sig.
1	(Constant)	,000
	PopulationDensity	,000
	RentIndex	,000
	TownHallDistance	,000
	RestaurantHotelDensity	,000

a. Dependent Variable: BookingDensity

Table 3.7: Model Coefficients

Next, table 3.7 shows the t tests for the slope and intercept, examining the hypothesis $H_0 : \beta = 0$ for each independent variable used. Here again, the null hypothesis can be rejected and all variables and the constant are statistically significant (p <0.001).

Finally, the assumption that the residuals are independent, normally distributed, and that they have equal variances for any x value, must be checked. The normal plot in figure 3.20 reveals however, that the residuals are not fully normal distributed and the model is slightly biased. It is likely that other independent variables could explain more variation in the data. [22] However, they are unknown or might not be measurable.

3.4.6 Analysis Results

In summary and as a result of this analysis step, the quantitative analysis reveals that booking density as manifestation of "success" within a city is dependent on local values of rent (positive relationship - the higher the rent, the higher the booking density in

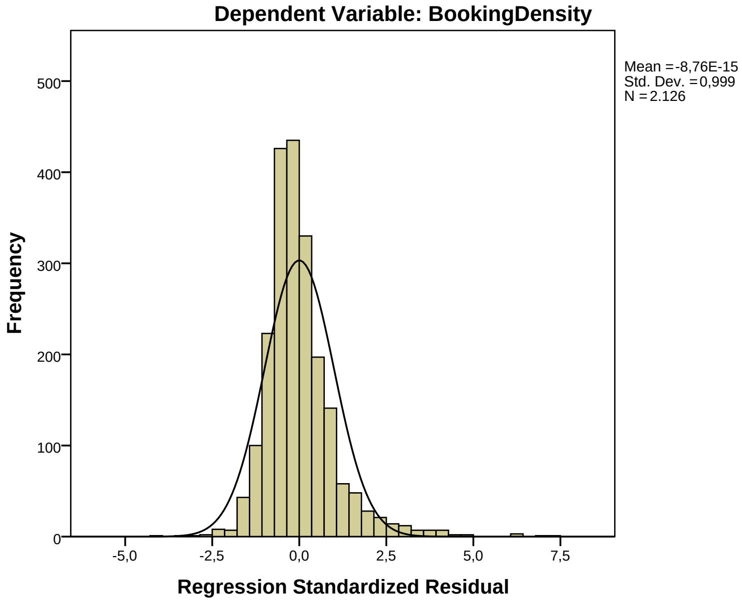


Figure 3.20: Standardized Residuals Plot

an area), town hall distance (negative), population density (positive), and lastly restaurant and hotel density (positive). Eight other factors show a relationship to booking density but a multivariate consideration reveals their insignificant contribution when the four mentioned variables are combined in a regression model.

Nevertheless, also other success factors that were determined in this section must be kept in mind when developing the model-based framework in chapter 4. Some factors could not be determined quantitatively because they are either not measurable, there is no data available, or they are influential on a wider scale like, for example the city wide taxi price, which could still be very influential for local adaptation.

It must also be noted that results vary from previous approaches (see discussion in subsection 2.4.3), which emphasizes again the difference of free-floating to traditional station-based carsharing systems.

Chapter 4

Development of the Model-Based Framework

4.1 Chapter Summary

Based on the knowledge base acquired in the previous chapter from theory, structural and empirical data, and expert knowledge, this chapter aims to develop a model-based framework for the local adaptation of free-floating carsharing systems. This framework and its implementation in software are the core results of this dissertation and answers the research question. First, this chapter clarifies and defines the model-based framework as well as its aims are outlined. Modeling and model calibration follows next and also draws on analysis findings regarding success manifestations and success factors as they are elements of the models. This results in five individual models of the operating area, fleet size, charging concept, fleet mix, and of the price.

In a next step, all five models are joined in the model-based framework, which also accounts for the interrelationships between the five models. This model-based framework guides decision makers on the local adaption of their free-floating systems and consists of three units: First, there is an input side, consisting of external success factors stemming from the city, for example population density. Second, there is a functional unit which contains the modeled logic that transforms the input variables into outputs. These outputs are given in unit three, representing aspects that have to be locally adapted such as a suggested fleet size. For verification and to bring the model-based framework in application, a prototype Decision Support System is developed and applied to Chicago, IL, USA.

4.2 Definition, Scope and Aims of the Model-Based Framework

When developing a model-based framework, it must be understood what is meant with this term. First, ”model” should be defined. In literature, this term is used and defined in numerous ways including ”a standard or example for imitation or comparison”, ”a pattern or mode of structure or formation”, and ”a simplified representation of a system or phenomenon, as in the sciences or economics, with any hypotheses required to describe the system or explain the phenomenon”. [238] On the basis of functional, structural or behavioral similarities to an original, a model is used to solve problems which cannot be solved with the original as this would be too complex or even impossible. [96]

In this research certain aspects of carsharing systems are modeled, hence representing a standard for the imitation of real-life pattern in a simplified way. For example, the operating area for free-floating carsharing can be determined through a model, simplifying reality through focus on key influencing aspects. The model imitates reality’s relationships of these factors with the operating area, and sets a standard for a variety of cases and environments. In other words, this model brings the complexity of reality in a simple equation which can be applied in a variety of settings, rather than expensively trying out different operating areas city by city. Accordingly, key aspects of carsharing systems that have to be locally adapted must be modeled.

In section 3.2 it is extensively analyzed which aspects of free-floating carsharing systems should or must be locally adapted, even though in general it is found that standardization is sought wherever possible. The qualitative discussion gives valuable input for companies on what to adapt locally. There is a wide variety of locally adaptive elements that have to be considered but as a result of the discussion, five aspects need further investigation and modeling: the operating area, fleet size, charging concept, fleet mix, and the price.

These individual models will then be joined in a framework and therefore a model-based framework is developed. A framework is ”a structural plan or basis of a project” or ”a structure or frame supporting or containing something.” [237] For example, in computer systems, ”a framework is often a layered structure indicating what kind of programs can or should be built and how they would interrelate”. [189] In the case of this research, it is not computer programs that are contained in a framework but the five individual models that are developed. The framework structures them and brings them in interrelation.

The objective of the model-based framework is to enable and support decision makers when adopting free-floating carsharing systems to local markets. To do so, the framework must depict critical and important aspects to support decision makers who work in reality with its full complexity. People are unable to process all information and therefore it is crucial to know what is important in order to monitor and adapt it.

Adopted from Bogenberger, who defined ”ideal” characteristics for a ramp metering strategy [28], the following set of main features for the model-based framework is derived:

- FOUNDATION: The framework should be based on theoretical foundations and hence on reasonable assumptions and objectives, rigorous problem formulation, and efficient and accurate solution methods. This is ensured through research design in section 2.6 and this section.
- SUPPORT: Its main aim is to give support in the local adaptation of free-floating carsharing systems by providing decision-makers with an understanding of the environmental context and the consequences of their actions. Therefore, also an input validation or plausibility check should be included, giving feedback on the sensitivity of the decision made.
- ADJUSTMENT: Easily adjustable since factors and parameters will change over time and must be updated to keep models up-to-date and refine them.
- OPERABILITY: The implementation of the model-based framework at carsharing providers must be possible without extensive costs, training and computing efforts.
- COLLECTABILITY: The input data for the framework must be collectable without extensive primary research efforts. Therefore, it must be objective and quantifiable standard secondary data that is used as input for the models.
- TRANSFERABILITY: The basic structure of the framework must fit any carsharing provider and market.
- VERSATILITY: It must be assured that the framework can be used for electric free-floating carsharing as well as with conventional vehicle carsharing.
- DYNAMIC: It should show how changes within a city affect the carsharing system dynamically (new input data = new results).
- APPLICABILITY: The framework must be applicable to existing markets in order to optimize them according to the research and for new markets to plan for launches in new cities.

On the contrary, it is not aimed by the model-based framework to automatically compute definitive answers on how to locally adapt a free-floating carsharing system. The environment is changing constantly and there is an always changing and unpredictable number of ”soft” factors which must be considered when determining the local shape of a system - for example the presence of local partners, the business policy of a company, local politics and many more. To take this need for flexibility into account, the framework is considering ”soft” key issues that must always be considered and prescribes a qualitative alignment of some aspects.

A summary of this chapter was also submitted for the 2015 TRB Annual Meeting [208].

4.3 Modeling Locally Adaptive Aspects

4.3.1 Operating Area

The first aspect of free-floating carsharing systems that has to be determined and hence the first element of the model-based framework is the operating or business area. The operating area is the key element of a free-floating carsharing operation as it defines the geographic and to a wide extent also the demographic target market. For customers, the definition of a ”right” operating area is decisive for whether and how often they use the system, as section 3.4 revealed. Therefore, in theory, a larger operating area leads to a higher number of customers, bookings, and potentially longer booking durations. In reality however, operating areas cannot be arbitrarily large since the number of cars would grow uneconomically to ensure availability and vehicle distribution could become highly complex. The joint character of carsharing limits the flexibility to certain areas, as the car has to be picked up from a location within the operating area, where the previous user parked it. Consequently, there must be a sufficiently high probability that the car will be picked up from another user within short time. Only then the concept can be economic and realize positive ecological effects since a parked carsharing vehicle does not contribute in solving traffic problems and is a waste of resources. As a result, determining an optimal operating area depends on an a priori prediction of potential booking hot-spots within an urban area.

The possibility to designate an operating area and accordingly the possibility to offer free-floating carsharing hinges on the question regarding the possibility whether on-street parking is sufficiently available or not. In most cases, local authorities will answer this question by either allowing carsharing providers to purchase parking licenses or not. Another possibility is that municipalities do not allow parking in certain zones or areas, e.g. in Munich free-floating carsharing vehicles are not allowed to park in resident parking permit zones or in the downtown area. Next to these regulatory constraints, there might also be structural constraints (e.g. no space as for example in Tokio) that hinder on-street parking. In these cases, the definition of an operating area is strongly influenced or simply not necessary as free-floating carsharing might not even be realizable. In this case, other business models must be applied to the respective city, such as station-based carsharing which relies on parking spaces on private premises. For the framework, this factor must be considered qualitatively since there is no data on parking available in many cities, possible indicators like parking garage prices vary strongly internationally and from garage to garage, and lastly no data covers the local policy from municipalities towards free-floating carsharing. Some cities are convinced that free-floating carsharing helps them to achieve their targets whereas others have a different view. Also, parking regulations differ from market to market. For example, London alone consists of 33 boroughs with independent parking authorities and regulations. For these reasons, no standard statistics can be used for modeling but rather, dialogues with potentially interesting cities have to be sought to find out about the possibility to carry out a free-floating carsharing operation in the respective cities.

Apart from this crucial factor, a regression model is built to model the operating area. Derived from analysis findings in section 3.3, booking density is the ideal predictor for where to set the operating area as it indicates high local demand. The regression model can consequently be based on the four determined "key" success factors of population density, city center (defined as the location of the town hall) distance, rent index, and hotel and restaurant density (see analysis in section 3.2. With these factors it is possible to determine success, which is manifested in booking density. Furthermore, such a model appears useful since all four input factors can be measured "objectively" in every city and acquiring data should be easily possible. Also the combination of the four makes sense since city-center distance and hotel-/restaurant density are good indicators for leisure or shopping trips. These trip purposes are the most frequent as a survey among DriveNow customers (n=629) shows (see figure 4.1). Population density on the other hand represents the existence of a potential customer base and uses cases where the home is involved, which is the case in 61.1% of all bookings as section 3.3 revealed. Also visiting friends, for which 58% of DriveNow customers use the service as figure 4.1 shows, is covered by this factor. Finally, rent is an indicator for mixed use in an area. Pure residential areas potentially have higher booking rates in the morning, early evening and on the weekend whereas pure nightlife areas with many restaurants will not have many bookings during the day but many at night. The combination of both is hence ideal. Furthermore, areas with higher rents can be considered more attractive and the carsharing target group of young urban early adopters are likely to live in these areas.

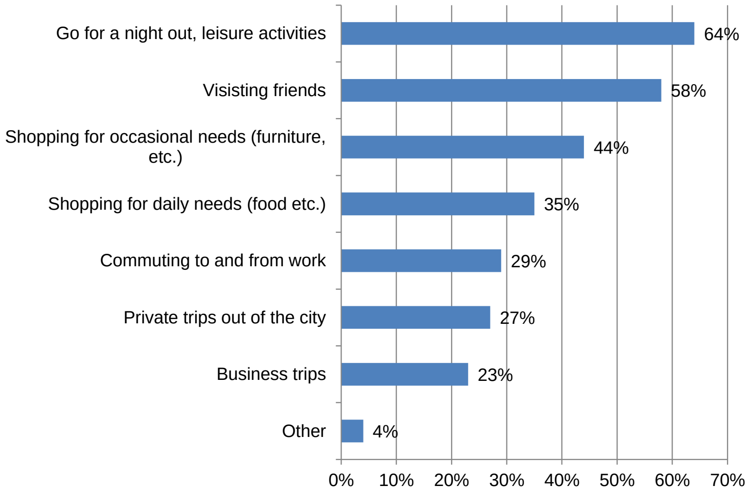


Figure 4.1: Survey: Trip Purposes of DriveNow Users [26]

In order to develop the regression model for the derivation of the operating area, two major variations to the previously determined model in section 3.4.5 must be considered. First, to ensure transferability to a variety of cities worldwide, it is important to relativize all success factors. For example, cities vary greatly in their size. In a big city, a segment that is 8,000 meters from the city center might be still very central whereas in a small city this could already be beyond the city borders. To relativize the factors, indices for each success factor must be calculated, comparing for each segment the absolute value of a factor. For example, a 8,000m city center distance must be compared with the average value of a factor within the analyzed city, e.g. an average city center distance of 9,500m over all segments. To generalize, let x_{it} be the value of an explanatory (success) factor i in segment t of an observed city. Then the index p_{it} is derived the following way:

$$p_{it} := \frac{x_{it}}{\bar{x}_i} \quad \forall i \tag{4.1}$$

where $\bar{x}_i = \frac{1}{T}\sum_{t=1}^{T} x_{it}$ is the average of the explanatory variable i in the observed city (T is the number of segments in the city).

The second major variation of the model compared to the previous regression model is that the calibration of the model is carried out with the whole city area. To determine success factors, only areas that were regularly frequented were considered. The goal of this step however, is to predict potential booking hotspots and the whole city must be considered to do so comprehensively. Derived from the prediction of these inner-city hotspots, decision makers are aided in defining business areas successfully. However, the data with which the model is calibrated with is biased inasmuch as it stems from cities which already have operating areas that were determined through local knowledge and testing. Therefore, the model will return operating areas that are similar to those defined. It is unlikely that testing on a greenfield with no operating area and a free-floating model comprising a whole urban area would return completely different results but this research cannot carry out such an expensive and huge scale experiment. Therefore, this limitation is inherent in this dissertation and must be considered when interpreting results.

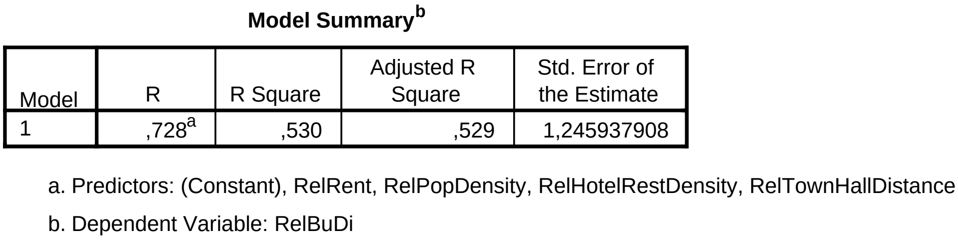
As a result of an ordinary least squares (OLS) regression performed with real GPS booking and customer data as well as structural data from Berlin and Munich, the following model appeared:

$$bd_i = -1.52 + 0.5pd_i + 0.274rd_i - 1.023thd_i + 2.773r_i \quad \forall i \tag{4.2}$$

- bd_i is the index of booking density (=relative booking density) of segment i
- pd_i is the index of population density of segment i
- rd_i is the index of restaurant and hotel density of segment i
- thd_i is the index of the distance from segment i to the city center (town hall) of the considered city
- r_i is the index of the rent of segment i

With a $\bar{R}^2$-value of 0.53 this model explains 10% more variation than the previous absolute model in section 3.4.5. This improvement can be accounted to the fact that both cities already have existing operating areas which exclude ”unattractive” areas. These areas have little or no booking density not only because they have little carsharing potential, but also because they are out of the existing operating area. Now these areas are considered in the calibration of the model, whereas before this was not the case. Table 4.1 gives a model summary.

Next, table 4.3 shows the ANOVA (Analysis Of Variance) table for the regression. Again, there are two sums of squares – the regression and residual (or error) sums



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,728[a]	,530	,529	1,245937908

a. Predictors: (Constant), RelRent, RelPopDensity, RelHotelRestDensity, RelTownHallDistance

b. Dependent Variable: RelBuDi

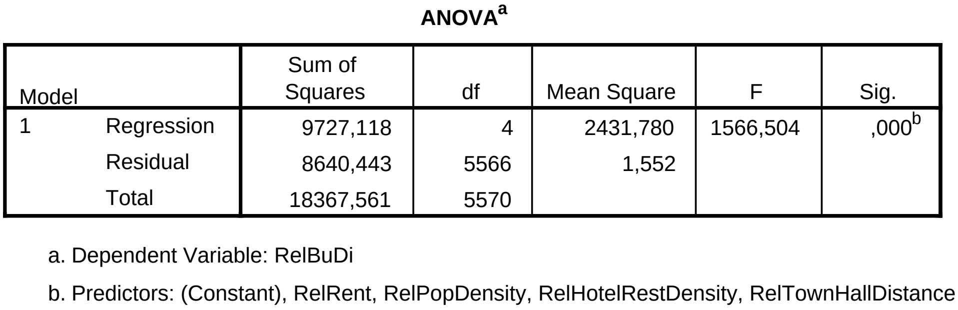
Table 4.1: Model Summary

of squares. The variance of the residuals is the value of the mean square error or MSE and amounts to 1.552. Compared to the variance of booking density of 3.298 (see descriptive statistics of booking density in table 4.2), scattering is reduced by the factor 2.13.

	N	**Min.**	**Max.**	**Mean**	**Std. Deviation**	**Variance**
Relative Booking Density	5,571	0	19.81	1	1.81	3.298

Table 4.2: Descriptive Statistics

Also in the ANOVA table the F test can be found, testing the hypothesis that the independent variables show no relationship to booking density. For this model, the value of the F test is F(4, 5566) = 1,566.504 and the table shows that this is significant ($p < .001$) and it can be determined that the model provides a significantly better prediction than the mean value. Hence, the hypothesis can be rejected and the overall model can be regarded as significant. [232] As a result, the index of booking density is related to the indices of population density, rent, city center distance, and restaurant and hotel density.



ANOVA[a]

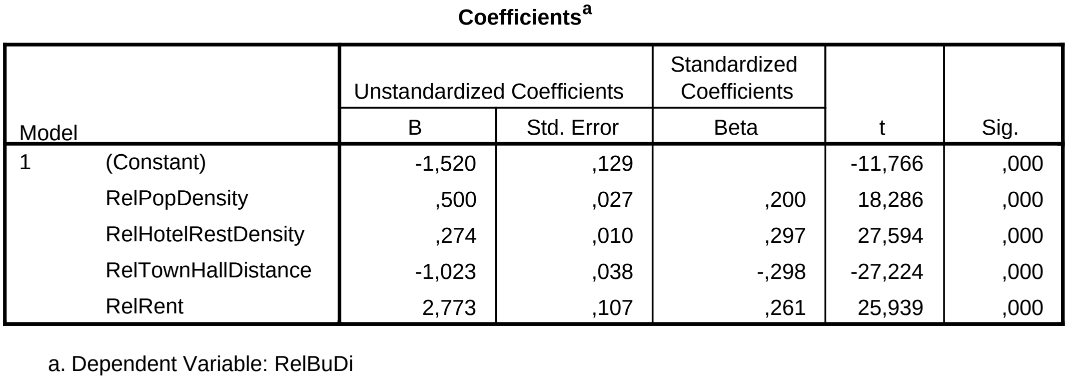
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9727,118	4	2431,780	1566,504	,000[b]
	Residual	8640,443	5566	1,552		
	Total	18367,561	5570			

a. Dependent Variable: RelBuDi

b. Predictors: (Constant), RelRent, RelPopDensity, RelHotelRestDensity, RelTownHallDistance

Table 4.3: ANOVA (Analysis Of Variance) Table

Information about the coefficients of the model can be found in table 4.4. While the unstandardized coefficients are part of the model equation, the unstandardized coefficients or slopes can be interpreted the following way: 1 index point increase in distance from the city center reduces the index of booking density by 0.298. In general, these indices can be interpreted as percentages, e.g. a rent index of 0.5 indicates that the rent in this segment is only 50% of the average rent in the respective city. Consequently, the arithmetic mean of all segments of a city is always 1. Also, the standardized or beta coefficients tell that the index of the distance to the city center is the most powerful independent variable in this model, followed by the indices of restaurant and hotel density, rent, and lastly population density.



Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1,520	,129		-11,766	,000
	RelPopDensity	,500	,027	,200	18,286	,000
	RelHotelRestDensity	,274	,010	,297	27,594	,000
	RelTownHallDistance	-1,023	,038	-,298	-27,224	,000
	RelRent	2,773	,107	,261	25,939	,000

a. Dependent Variable: RelBuDi

Table 4.4: Model Coefficients

Furthermore, table 4.4 shows the t tests for the slope and intercept, examining the hypothesis $H_0 : \beta = 0$ for each independent variable used. Here again, the null hypothesis can be rejected and all variables and the constant are statistically significant (p <0.001).

As a final check of the model, the assumption that the residuals are independent, normally distributed, and that they have equal variances for any x value must be examined. As expected, just like in the previous regression model in section 3.4.5, the normal plot reveals that the residuals are not fully normal distributed (see figure 4.2) and the model is slightly biased, making it likely that other independent variables could explain more variation in the data [22] but they are still unknown or might not be measurable.

This model can be used for free-floating carsharing with conventional vehicles as well as with electric vehicles. It must be noted however, that this model does not contain one key aspect of carsharing with electric vehicles - charging infrastructure. Currently, there is no comprehensive available dataset which could have been included in

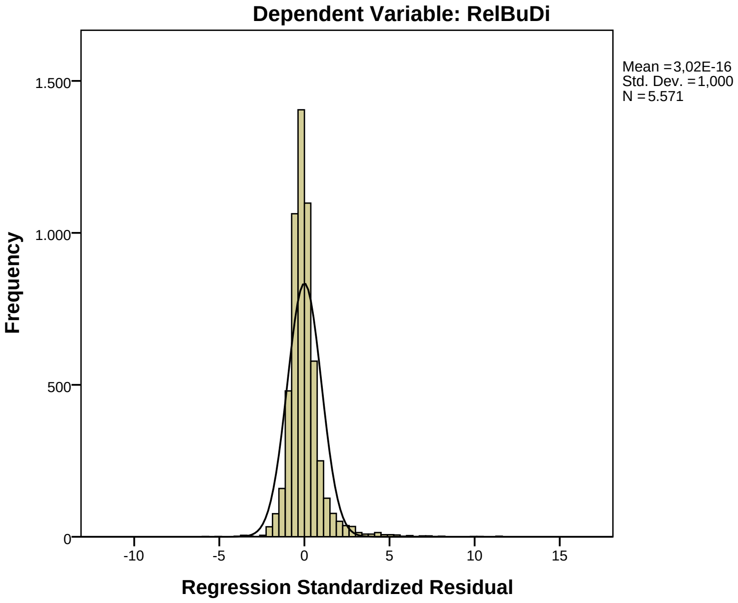


Figure 4.2: Standardized Residuals Plot

the formulation of the model. Hence, the topic must be explored theoretically. A possible success factor for determining the business area for a carsharing concept with electric vehicles is the existing charging infrastructure. When a city has a well-developed charging infrastructure then users have many possibilities to recharge, reducing range-anxiety and keeping operation costs for providers low. If there is no charging infrastructure available, the model might help to determine where charging depots might be established or what type of charging technology is needed. In hot-spots for example, the turnover of cars is quick and hence potential charging time is limited. Therefore, quick-charging technology might be employed as users of electric carsharing might find it convenient to find a charging station near a hot-spot. At such points there is usually only limited parking available and a charging station would be a non-monetary incentive to use electric carsharing because of the attractiveness of a parking spot. On the other hand, cold-spots could be equipped with slower and cheaper charging stations as vehicles probably park a longer time in this area as demand is lower (for a more detailed discussion please refer to section 4.3.3). Consequently, the spatial distribution and technology of chargers should be examined qualitatively and the determination of the operating area might be aligned to this factor, e.g. through the inclusion of an area that appears not to be very attractive but has a good charging infrastructure.

In a next step, the model is applied to Düsseldorf because the model was calibrated with GPS booking and customer data from Berlin and Munich and with the help of real booking data from Düsseldorf, the model can be validated. First, indices are built for all four independent variables and for each segment of Düsseldorf (n=593). This is followed by step two, where the model is applied to each individual segment to calculate an index for booking density for each segment. With the help of a GIS (geographic information system), the result is mapped in figure 4.3 (top left). Here, the colors are chosen according to five quantiles (=quintiles) of the resulting booking density indices for all segments since numerical values do not have a practicable meaning. It is rather the spatial distribution of hot-spots that is of interest. Accordingly, the colors can be interpreted as categorization of attractiveness for a segment: red indicates a very attractive, orange an attractive, yellow a medium attractive, bright green an unattractive and dark green a very unattractive segment. This information can be used for outlining operating areas as well as it can give valuable input for city negotiations, e.g. with which boroughs it is reasonable to negotiate parking permits.

When determining the operating area, these maps can be of great support but it still needs expert verification since the model is ”blind” and only relies on the four independent input variables. For example, the model for Düsseldorf indicates an area/segment as attractive that comprises mostly of water. This is due to the fact that this segment has a small land proportion in relation to the overall segment, which determines the data values for rent, population, and hotel and restaurant density. In addition, the segment is relatively central which results in a rather attractive area even though there can naturally not be many bookings except on the shore. Furthermore, each segment is a discrete space and from a customer’s view it could hardly be comprehended to have a variety of little and disconnected operating areas without any perceptible borders. Ideally, the operating area comprises only attractive areas, is contiguous, and orientated on a natural border (big ring streets, train lines, water lines, etc.). This shows that a simple city map combined with the mapped model result could potentially lead to a sensible determination of the operating area.

The validity of this approach is now tested with actual GPS booking and customer data of Düsseldorf. Figure 4.3 (top right) shows a heat map on booking density of Düsseldorf with the actual operating area indicated as black line.

The heat map clearly shows the influence the operating area has on booking behavior as parking the vehicle outside the operating area is forbidden/penalized with fees. As a consequence, areas outside the operating area have lower booking densities than they might naturally have as well as border areas have higher booking densities since people living outside the operating area will drive to the border, end the booking, and continue with another means of transport to reach their destination. These effects must be accepted however, since there is no data on what would be without a predefined operating area.

The comparison of the modeling result with actual booking data reveals a high visual conformity regarding the rough border of an operating area. However, there are also clear deviations, as indicted in figure 4.3 on the bottom, which depicts the model residual. However, most can be explained when looking at a city map. Segments with high shares of water (as previously explained), parks, or industrial areas were indicated more attractive than in reality because they mostly also had smaller residential/recreational areas that determined data values regarding rent and restaurant density. The highest deviation with more than 10 standard deviations occurred in the city center in an area known as the "longest bar in the world". [259] Logically, the model assigns this area a very high attractiveness; however, it is a pedestrian zone and no cars can enter the area for which reason there are no bookings in reality. This again shows the limitations of the model and the need for expert evaluation of the results. Nevertheless, the model proved its high applicability as deviations (over- and underestimations of the model) occur mainly within hot-spot areas. This does not influence the determination of a business area because the absolute forecast (or the level of relativity) of the booking density is indifferent for this decision. Areas with standard deviations >0.25 that are outside of the actual business area can again be explained through segments with a high share of water, parks, and industrial areas.

Furthermore, also a cross-evaluation was conducted. In the development, the model was calibrated with GPS booking and customer data from Munich and Berlin and in cross-evaluation, the model is calibrated first with data from Düsseldorf and Munich and second with data from Düsseldorf and Berlin. Even though there was a shorter period in which actual booking data was collected in Düsseldorf, as a result, the model proved to be very stable. Both cross-evaluations returned similarly high $\bar{R}^2$-values with significant overall models and significant coefficients.

To evaluate the model's overall validity further, it was applied to Hamburg in order to examine whether it is also applicable to other free-floating carsharing providers, here namely car2go. Since there is no booking data from car2go, only the actual business area of car2go is considered which is freely available on the provider's website. Car2go is present in Hamburg for more than two years [67] at the time of this research and since its launch the operating area was expanded four times [58] and hence grew organically according to the local experience which was made. Thus, the actual operating area can be considered as mature. The result of the model's application to Hamburg can be seen in figure 4.4. It shows, that the modeled results have a good fit with the actual operating area. Major overestimations were made south of the actual operating area where there is mostly indutry and a harbor and west from the operating area, which is an exclusive residential area and car2go might have decided that no sufficient demand can be expected in this area (e.g. due to the use of simple smart vehicles that might not attract wealthy customers).

Overall, the evaluation of the developed regression model for the determination of the operating area for free-floating carsharing systems shows positive results. The model appears very useful for its purpose when it is applied with common sense. Considering more data, e.g. trafficability, would mean gathering primary data and therefore high efforts and expenses. This could lead to more accuracy but it is opposed to the aimed features of the model-based framework and most likely not worth the effort in reality, since the operating area will be planned by experts with at least some degree of simple verification of the results, e.g. with a city map or through local inspection.

A summary of this section was also presented at the 2nd Symposium of the European Association for Research in Transportation (hEART [209] as well as it was submitted for the Research in Transportation Economics journal [210].

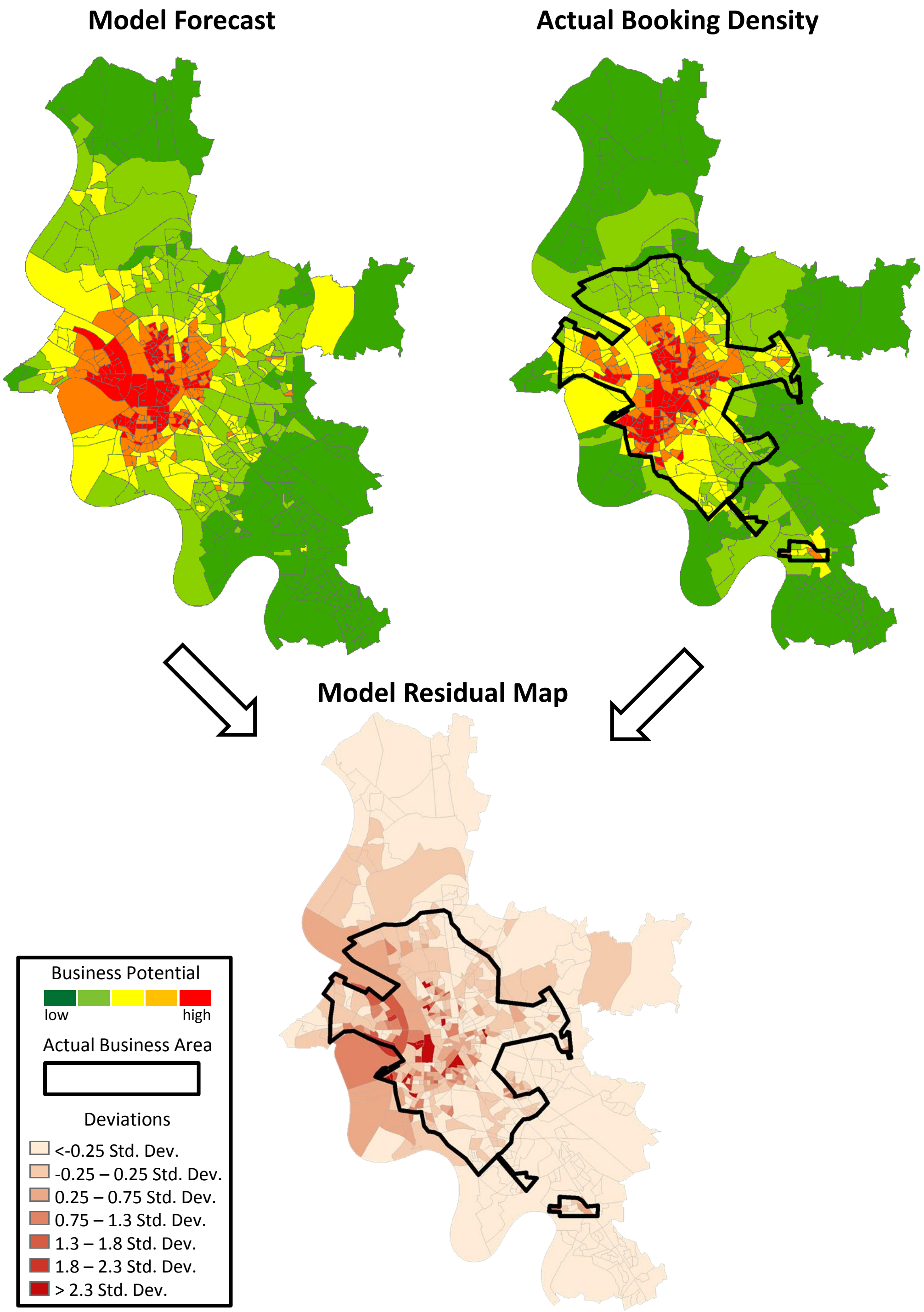


Figure 4.3: Model Validation Düsseldorf

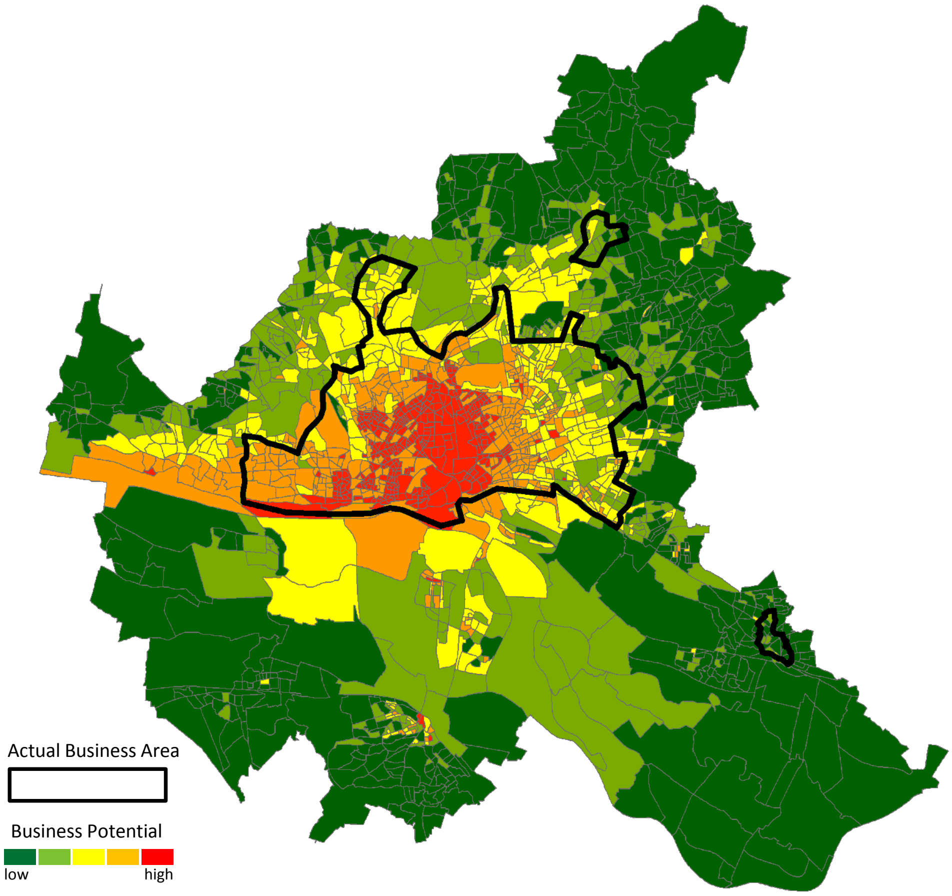


Figure 4.4: Model Forecast Hamburg incl. car2go Operating Area (black line)

4.3.2 Fleet Size

Availability is Key

The second aspect of a free-floating carsharing system that must be considered in modeling is the fleet size. Section 3.3 shows that there are direct relationships between the number of bookings (booking density) and booking duration in an area and they are consequently interchangeable variables for the use as a success measure to which the fleet size must be optimized to. In the context of fleet size determination, the link of booking time to utilization and hence availability and fleet size must be clarified:

$$\begin{aligned} \textit{Total Booking Time (per day)} &= 24h \times \textit{Fleet Size} \times \textit{Utilization} \\ \Leftrightarrow \textit{Fleet Size} &= \frac{\textit{Total Booking Time (per day)}}{24h \times \textit{Utilization}} \\ \Leftrightarrow \textit{Utilization} &= \frac{\textit{Total Booking Time (per day)}}{24h \times \textit{Fleet Size}} \end{aligned} \tag{4.3}$$

From this it follows that if there are more cars in the system, utilization decreases and the other way around (ceteris paribus). This means that carsharing providers can directly control utilization by increasing or decreasing the fleet size. At a first glance, providers might want to achieve high utilization rates for profitability reasons. This however might not be sensible in the long term. Tuning the fleet size according to the maximization of utilization will influence the service quality. This is crucial as availability is a key to the concept (see subsection 3.4.3) and therefore the attractiveness of the offer is directly influenced. Operators should rather determine a target utilization they want to reach in order to find their optimal balance of customer satisfaction through availability and costs. This always depends on the individual positioning, aspiration, and cost structure of the respective provider.

As a consequence, utilization should not be a target variable but rather be the result of fleet size and booking time. This booking time must be maximized through ensuring a certain basic availability. An initial point for this is the ”service quality” principle or ”ideal” for a free-floating carsharing system, that every customer should have an available vehicle within an acceptable distance at all time. Ideally, this also leads to an optimal utilization of the individual vehicle, since full customer satisfaction through a reliable and available system should skim the market potential best. The determination of success factors in subsection 3.4.3 also showed that availability is a key for many customers, which was confirmed by a small survey among customers from DriveNow in Germany (n=38). According to this survey, 95% of people stated that the location of the car is important, whereas only 27% are interested in the type of the vehicle. [21] Furthermore, without an offer (a car) there can be no bookings.

Availability would ideally be defined as the percentage of potential customers who look for a car and successfully find one. Unfortunately, it is unknown how many potential or interested customers there are. A possible solution could be to compare the number of queries through the smartphone application with the number of actual bookings but this data appeared to be randomly distributed and not related to booking data and accordingly, no conclusions could be drawn from it. Adopted from Barrios "patch-based-availability" [20, 19, 18], another approach is to define availability as spatial coverage of the service within the operating area. Here, availability represents the ratio of the area served to the total operating area. The area served is understood as the walking area around a car because only if potential customers are within this walking area, they will end up booking a car. Otherwise, potential customers will choose a different mode of transportation. Since the operating area should be defined as attractive area, providers can expect demand everywhere in this area as well as customers expect to be served within this area. Therefore, the spatial coverage of the service appears as a very suitable measure for availability and service quality.

The acceptable walking area depends on an individuals' willingness to walk and naturally fewer cars are needed when people are willing to walk longer to reach one. Car2go states from experience that the concept does not work with fewer than four cars per square kilometer [154] which corresponds with the limitation of DriveNow and car2go to reserve cars 15 minutes in advance only as well as with experts' who widely agree that people are not willing to walk more than 5-10 minutes (see subsection 3.4.3 and [66]). In a city, five minutes of walking translate to a traveled beeline of roughly 250 meters on the map due to traffic lights, turning, etc. [222] This 250 meter radius around each car as vehicle-specific "commuting area" or "walking circles", translates in turn to 5 vehicles/km^2 and is therefore consistent with the statement of car2go, being a slightly more "pessimistic" assumption. Since this fosters customer satisfaction and hence the diffusion of the concept, 250m appear as good general indicator.

Input-Variable Operating Area

Considering these walking areas around each car, the fleet size can be easily determined when knowing the size of the operating area because the bigger the area the more cars are needed to ensure availability. The extent of the operating area can be determined with the previously developed regression model through summarizing all segments that are chosen to be part of the operating area, resulting in a single number, exemplarily 250km^2 for Berlin.

The number of cars to fulfill these arguments can easily be determined:

$$Fleet\ Size = Number\ of\ cars\ to\ fulfill\ the\ willingness\ to\ walk = \frac{Area\ of\ Operating\ Area}{Area\ of\ Walking\ Circles}$$

Having determined this ideal number of vehicles ensures an available vehicle within a certain beeline across the city and again, 250m appear reasonable. This is also depicted in figure 4.5 and relies further on the assumption of a uniform distribution. This is not a realistic assumption however and its implication will be discussed shortly.

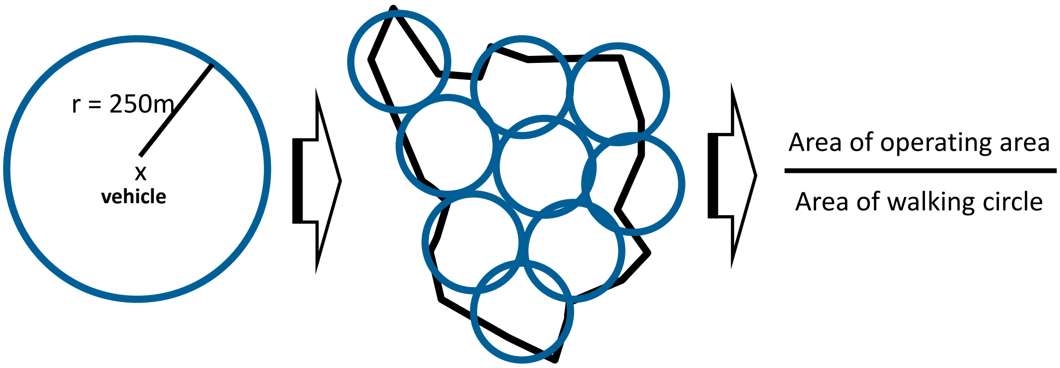


Figure 4.5: Illustration of a Simplified Approach to Determine the Fleet Size: Number of Cars to Fulfill the Willingness to Walk

Input-Variable Utilization

As discussed, the utilization of the fleet must be set individually by each provider to meet an optimum of availability and costs. Here it is especially important to consider that utilization – as defined above – is an average value over a day. Utilization strongly fluctuates throughout the day and providers should set their utilization targets considering this. Figure 4.6 shows a typical utilization curve derived from real GPS booking and customer data from Berlin and Munich for weekdays and weekends at a target utilization rate of 15% in a system with 403 cars. It becomes apparent that in weekday peaks, this translates to ca. 33% utilization. When assuming the same curves, this also means that it is not possible to reach more than 45% utilization because at this point, weekday peak utilization lies at 100% and no more cars would be available.

Even when the target utilization is set thoughtfully, it will fluctuate in reality because the number of customers and bookings changes constantly in the diffusion process (see also figure 3.5). When approaching a new city, initially there are no customers

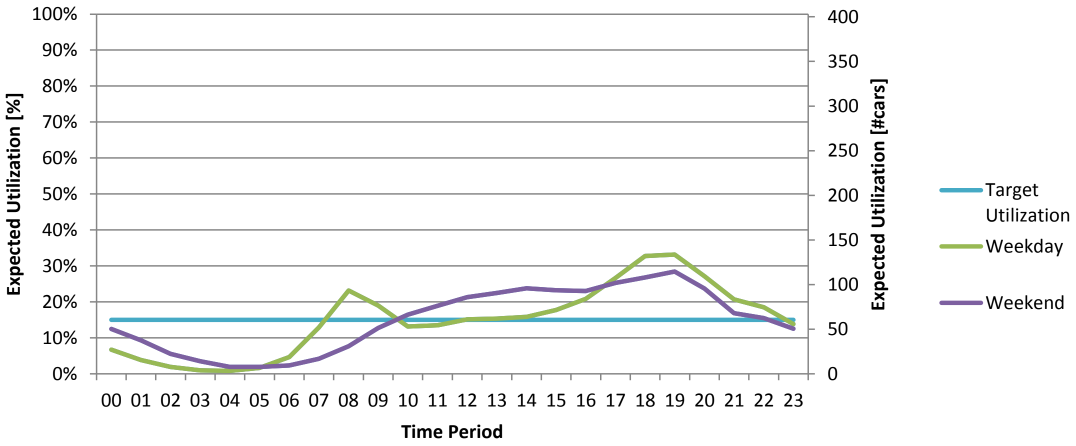


Figure 4.6: Typical Utilization Curve for Weekdays and Weekends

but until saturation is reached, the number of customers will grow and so will the number of bookings. Having a fixed number of cars, utilization will grow accordingly and every utilized vehicle is a potential gap in availability as it takes vehicles out of the system, leaving behind a gap for other potential customers. This is illustrated through the red gap in figure 4.7.

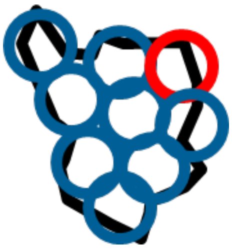


Figure 4.7: Illustration of a Simplified Approach to Determine the Fleet Size: A Utilized Vehicle Leaves an Availability-Gap

In this definition of utilization, the technical availability of the vehicles must be included as well because a certain part of the fleet is constantly not available due to maintenance, service blocks, refueling through the provider, charging times (which depend on the charging concept and technology, see also subsection 4.3.3 and 4.3.4), and technical problems among many other things.

As a result, there must be enough cars to allow for utilization whilst ensuring availability (=service quality) at the same time:

$$\textit{Fleet Size} = \textit{Number of cars to fulfill the willingness to walk} * (1 + \textit{Utilization})$$

Further, utilization is a variable to which the number of cars has to be adapted to constantly to keep utilization at the same level whilst the customer base grows. Ideally, providers could constantly increase the fleet size and start with a utilization of

0% to realize the maximum saving potential. Figure 4.8 illustrates this exemplary for a fleet size of 403 cars at a target utilization of 15% and an assumed constant customer behavior. The red line shows the increasing fleet from 0% utilization until 15% target utilization is reached. Alternatively and depicted by the blue line, providers could start with their target utilization configuration of the fleet size, keep it constant and once the target utilization is reached, increase the fleet to keep utilization at this level.

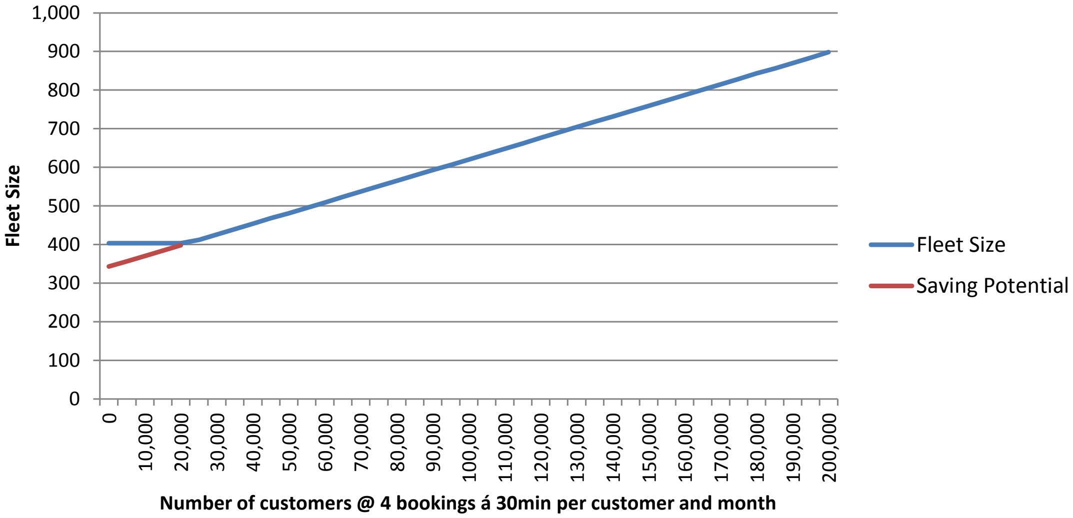


Figure 4.8: Illustration of the Continuous Adaption of the Fleet Size to Customer Growth

Input-Variable Spatial Coverage

As previously mentioned, this determination only works under the assumption of a uniform distribution of vehicles - an assumption that is not realistic and the equation above will not lead to 100% availability as suggested. To some degree this is acceptable or even good, since the spatio-temporal demand is not equally distributed either. However, an unequal distribution reduces availability at some points as illustrated in figure 4.9. To avoid this, relocation strategies might be applied (see for example [255, 254, 20, 19, 130]). The basis for these strategies must be an accurate forecast of demand and an optimization of potential earnings and transfer costs. Ideally, there are only as many cars in the system as utilized by customers and a ”perfect” relocation strategy ensures 100% availability at the same time. Since demand is unknown a further potential solution could lie in setting a side condition to not only transfer cars to demand hot spots but also to assure spatial coverage throughout the operating area.

Unfortunately, transfers are costly and potentially ecologically questionable and therefore relocation strategies might not be an ideal solution to ensure availability. This will surely change in future when electric cars might have to be transferred back from charging hubs or when autonomous vehicles become reality but nevertheless, such relocation strategies exceed the focus of this dissertation.

Figure 4.9: Illustration of an Unequal Spatial Distribution of the Fleet within an Operating Area

Another way to ensure availability is to adjust the fleet size. Currently, this might be more feasible since it is often automakers themselves who provide carsharing services and therefore vehicle costs are potentially lower than wages for constantly reoccurring transfer drives. Also, more vehicles do not cause ”empty” transfer drives like relocation strategies as well as it will always be hard to forecast demand accurately since free-floating carsharing is spontaneous and often customers book a car away from home without planning the trip. If it is possible to increase availability through more vehicles, the diffusion of carsharing will be supported and with it its positive effects to our societies can become reality. Because it is only then, when a customer can rely on having a carsharing vehicle close by at any point in time, that a majority would agree to substitute private car ownership. Once this high number of carsharing vehicles is sufficiently utilized, also the effect of an increased land use through more parked vehicles will diminish and if one carsharing vehicle replaces a certain amount of privately owned vehicles, more cars will lead to better environmental effects.

There arises the question of whether how many vehicles are needed to guarantee certain availability. Setting the fleet size to guarantee availability at a specific location is not possible because it is a free-floating system, so cars can be parked almost everywhere within the operating area and this leads to an unequal distribution. In spite of that, increasing the fleet size will improve the situation and raise the probability, that there will be an available vehicle at any point in space and time.

Since there is no data available on different fleet sizes within a similar environment (same operating area, constant number of customers, etc.) no empirical evidence can be found on the effect of different fleet sizes on availability. To close this knowledge gap, a simulation-based approach is chosen. The goal of the simulation is to replicate the real world spatio-temporal vehicle distribution in order to be able to try out different combinations of fleet sizes and utilizations in the simulation environment. The results of these different combinations are different values for the availability or spatial coverage of the service within the business area, which was defined as the ratio of the area served to the total operating area. With the data gained from this simulation, providers can see which respective vehicle density results from their choice of spatial coverage and utilization targets.

The implementation of this simulation is executed in NetLogo, which is an agent-based programming language and programmable modeling environment. [261] In figure 4.22 a screenshot of the simulation model can be found .

Calibration and validation of the simulation is based on real booking GPS booking and customer data of a free-floating carsharing system because it is considered important to accurately reflect the spatio-temporal changes in vehicle distribution in the simulation as real (served *and* unserved) spatio-temporal demand is unknown.

The parameterization and calibration of the simulation is based on an average day in Munich and to reflect vehicle distributions, origins, and destinations accurately, inner Munich was divided in 10 zones based on traffic cells (see figure 4.10).

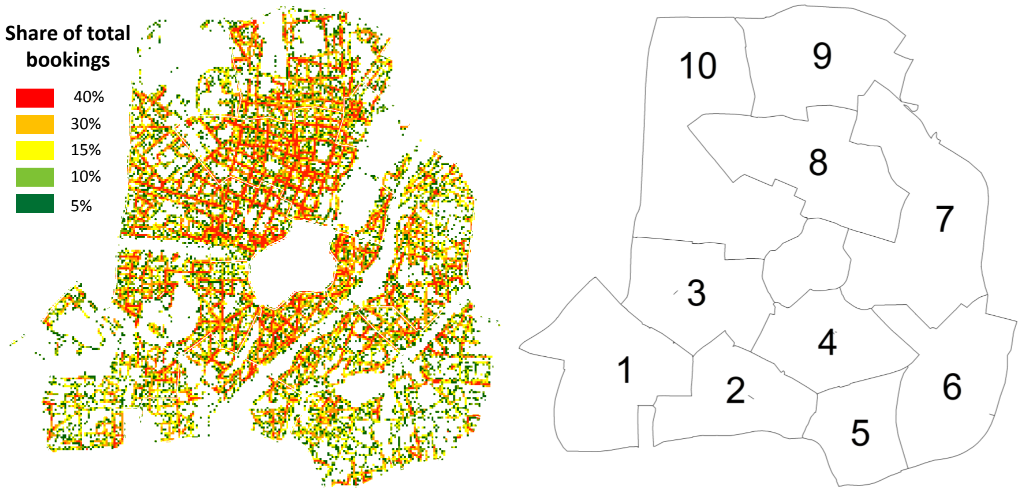


Figure 4.10: Heatmap of Munich in 33x33 Meter Patches for Simulation Calibration (Left) and Division of Munich in 10 Zones for Simulation Calibration (Right)

For each full hour between 6:00 am and 11:00 pm the number of cars in each zone was counted as well as the number of bookings that followed in the respective hour (e.g. no. of bookings in zone 1 from 6:00 to 6:59 am). This data is the basis for the calibration of the simulation, in which the spatio-temporal behavior is imitated. This means that cars in the simulation environment are spread among zones according to the GPS booking and customer data from reality. To allow for accurate behavior within each zone, additionally a heat map of Munich (see figure 4.10) was imported to the simulation environment. After trying out a variety of different scales and granularities, it appeared best to divide up Munich in patches of 33x33 meters and the color for each patch is determined by the booking frequency in the respective patch: the quintile with the most bookings was colored red, the second quintile orange, the third yellow, the fourth light green, and the fifth and least frequented quintile is dark green. Patches with no bookings (e.g. in parks or outside of the 10 zones) are hollow.

Similar to the analysis in figure 3.13, analysis shows that the top 20% of segments (red patches) within a city account for 40% of bookings, the next best 20% (orange) for 30% of bookings, yellow for 15%, light green for 10%, and the least frequented segments (represented through dark green patches) account for only 5% of bookings. The cars – or agents – in the simulation behave accordingly and within a zone, 40% of cars are on red patches, 30% on orange patches, and so on.

Since bookings do not end before the full hour and start afterwards, it is assumed that 50% of all cars that are booked within a time slice are currently driving at the top of the hour. This 50% estimation is based on the fact that in average bookings last about half an hour. In the simulation, those driving cars simply disappear because they are not parking and are hence not available to customers.

Once these steps are carried out, cars are distributed correctly and measurement begins. First, "Spatial Distribution of Bookings (Heatmap)" is calculated in order to check whether cars are distributed correctly within zones. Here, values will fluctuate slightly because of the randomness in the precise location where cars are placed. This is followed by the measurement if cars are distributed correctly among zones, called "Spatial Distribution of Vehicles (Zones)". Third, information is given on the temporal progress of utilization. These three plots are mostly given for information and verification purposes. The main information, spatial coverage, is given in the fourth and last plot. Here, all patches within a 250m radius around a car and within the operating area are counted and divided through the sum of all patches within the operating area. Figure 4.11 illustrates these radii around cars as blue patches. Therefore, spatial coverage gives the percentage of the operating area that is currently covered by the service.

Furthermore, the simulation gives a live count on how many reservations occurred so far in the simulated day as well as the vehicle density per km^2 is given.

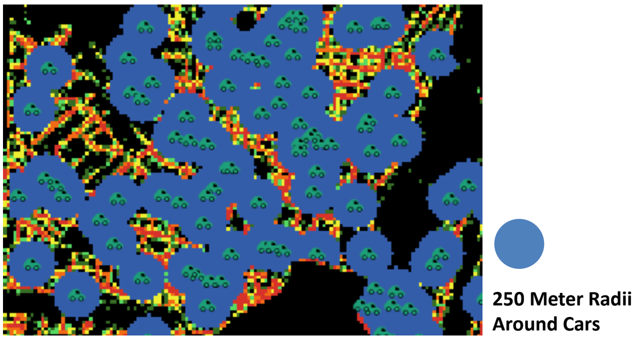


Figure 4.11: 250 Meter Radii Around Cars Symbolize Spatial Coverage in the Simulation Environment

After all these steps are executed, the end of a time slice / hour is reached and the simulation jumps to the next hour where all steps are repeated. This procedure repeats until midnight. Figure 4.12 illustrates the working principle of the simulation graphically.

To validate the behavior of the simulation, its result must be compared with empirical data. In order to be able to do so, the simulation is run with the same parameters as occurred in reality. On the observed day and within the studied area, 166 vehicles (=3.82 vehicles/km^2) at a utilization of 4.17% could be observed. With these inputs, the simulation returns the spatial-coverage depicted in figure 4.13.

To measure spatial-coverage in reality, a similar approach is chosen and performed with a GIS. First, parking locations and times derived from GPS booking and customer data are displayed on a map for every full hour on October 10, 2012 starting at 6 o'clock. Each car was then overlaid with a 250m walking circle buffer (see figure 4.14). These buffers were then erased from the operating area (see figure 4.15) and the difference of the remaining area to the operating area is the covered area. Setting this covered area in ratio to the operating area results in spatial coverage. To visually compare both approaches, figure 4.16 shows the spatial coverage in the simulation environment.

The result of this analysis can be found in figure 4.17 as well as the comparison of simulated with real world data. This difference consideration shows that the simulated spatial-coverage differs from real spatial-coverage in average by only 1.7%.

In order to make sure that simulation results are generalizable and can be applied to a variety of cities, simulation results are also validated with Berlin GPS booking and customer data. Figure 4.17 shows also the spatial-coverage in Berlin for October 10, 2012 and illustrates the difference to the simulation result. Different from the

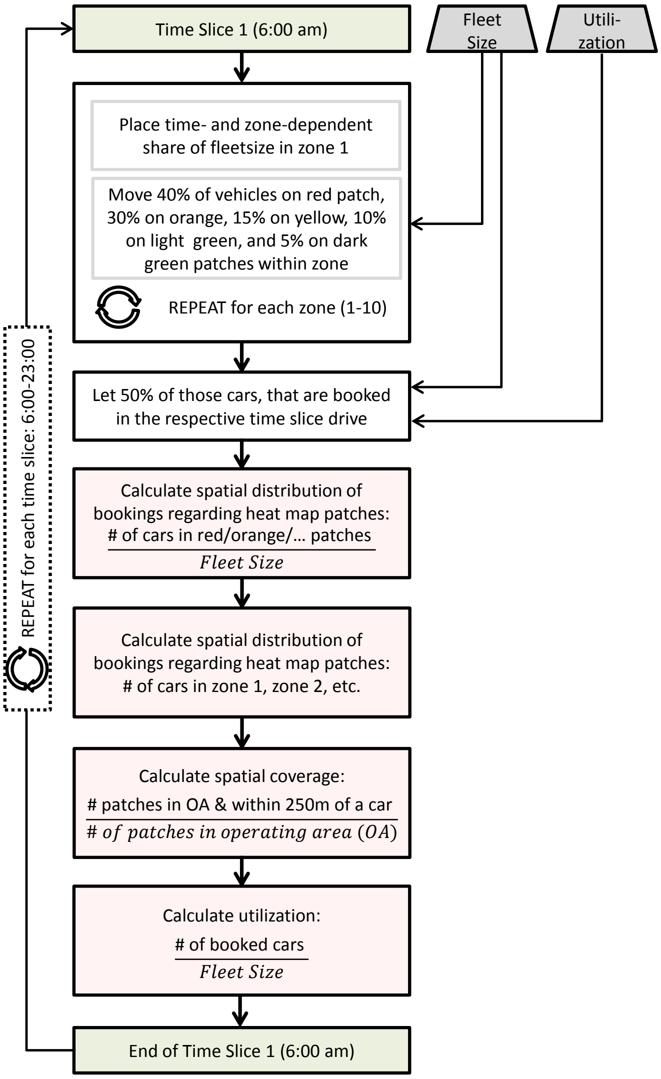


Figure 4.12: Illustration of the Simulation Working Principle

comparison with Munich, the simulation values are always slightly higher than the actual coverage – in average 3.7%. This can be explained by the fact that in Berlin the whole operating area is considered, whereas the simulation is based on Munich data from the inner ring of the city only. Nevertheless, the logically slightly higher forecast error of 3.7% can be seen as acceptable so that simulation results are regarded as generalizable to other cities.

The simulation can now be used for its intended purpose, testing different combinations of fleet sizes and utilizations to gain respective values for the availability or spatial coverage of the service. For this, the simulation is run from 1% to 45% utilization values in 1% steps as well as from 10 to 2,175 vehicles in steps of five cars,

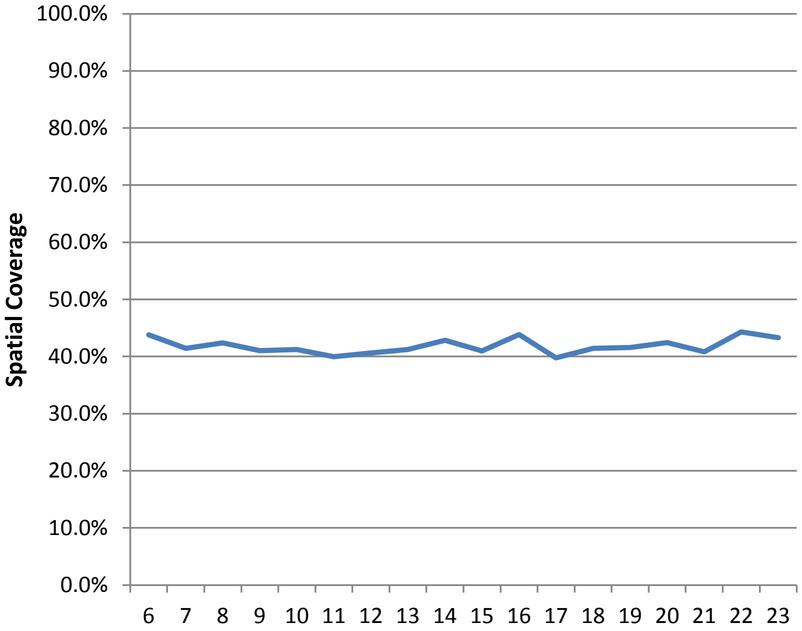


Figure 4.13: Validation: Simulated Spatial Coverage for Munich

equaling to vehicle densities from 0.23 to 50 vehicles per square kilometer. This results in 19,530 combinations of utilization and fleet size respectively vehicle densities and therefore in 19,530 simulation runs. To illustrate this, an example is given in table 4.5 as well as figure 4.18 shows the relationship of fleet size and spatial coverage at an exemplary utilization of 15% in an operating area of 100 km^2.

Run Number	**Target Utilization**	**Corresponding Vehicle Density** [*Veh.*/km^2]	**Resulting Spatial Coverage**
1,476	15%	5.75	49.9%
1,477	16%	5.75	48.7%
1,478	15%	6	51.3%
1,479	15%	5.5	47.9%
...	...	...	...

Table 4.5: Exemplary Extract of the Simulation Result Table

It can be seen that coverage is a logarithmic function of the vehicle density. The curve will vary depending on the chosen utilization as well as the fleet size depends on the operating area. In any city there will be parks, non-parking zones, water areas, etc. for which reason it is not possible to achieve 100% coverage, unless such areas are completely cut out of the operating area which however leads to customer confusion

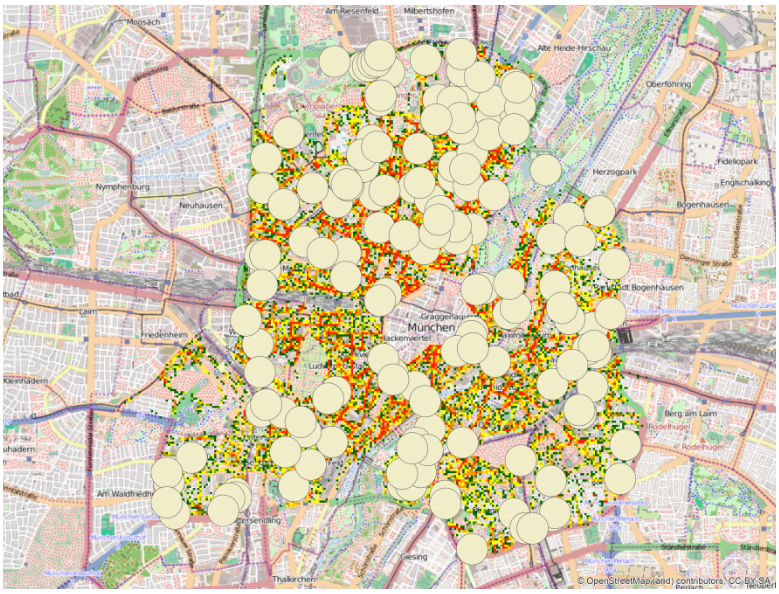


Figure 4.14: Validation: 250m Buffers around Parking Vehicles in Munich

and complex operating area borders. Apart from that, where no cars are allowed, customers can not expect to be served by a carsharing service. What also becomes clear is that moderate fleet sizes can reach a spatial coverage of up to 60% and only beyond this point vehicle densities increase disproportionally fast since saturation is reached. The graph in figure 4.19 shows the data in a three dimensional scatter plot in order to illustrate the effect of utilization on vehicle densities. The (slightly) crooked arch shows that in order to reach the same spatial coverage at higher utilization rates more vehicles are needed but the effect of utilization on the fleet size is much lower compared to spatial coverage. Nevertheless, considering utilization is of high importance when looking at peak availabilities as figure 4.6 shows.

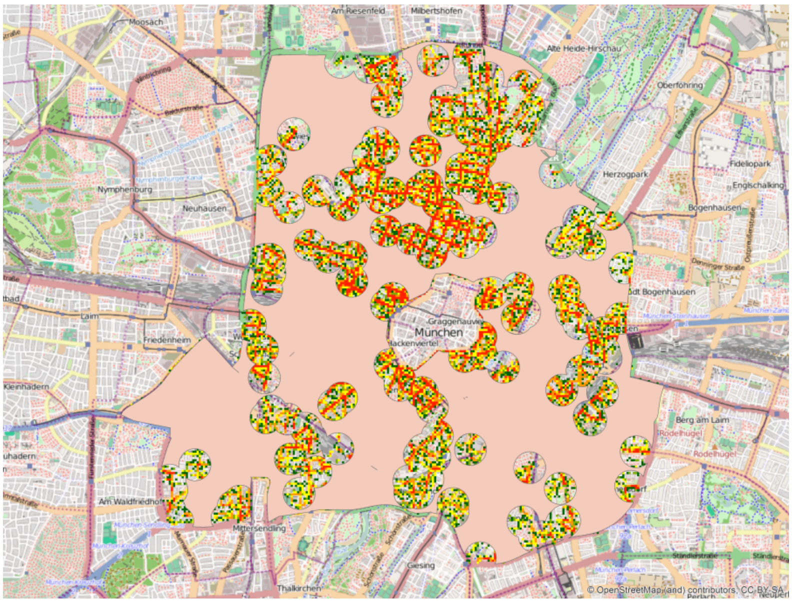


Figure 4.15: Validation: Simulated Spatial Coverage for Munich Cut Out from the Operating Area

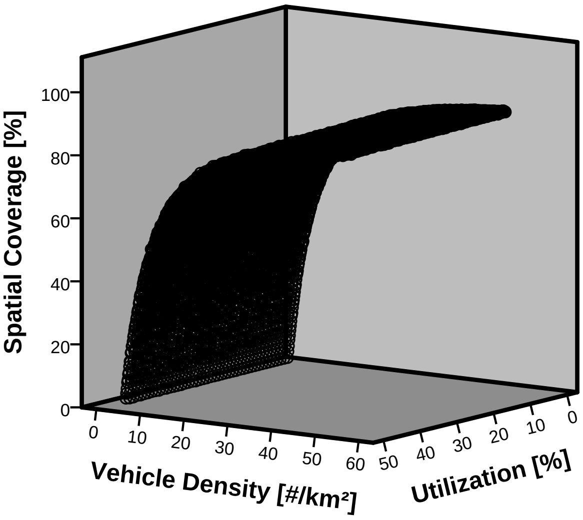


Figure 4.19: Three Dimensional Scatter Plot on the Relationship of Spatial Coverage, Vehicle Density, and Utilization.

These simulation results can now be used for the determination of the fleet size. To stick with the example from table 4.5, a provider could choose a spatial coverage of 49.9% and a target utilization of 15% and as a result must choose a vehicle density of 5.75 vehicles per km^2. Through the extensive amount of combinations simulated, a strong database was created from which providers can determine their desired vehicle density, resulting from their choice of spatial coverage and utilization targets.

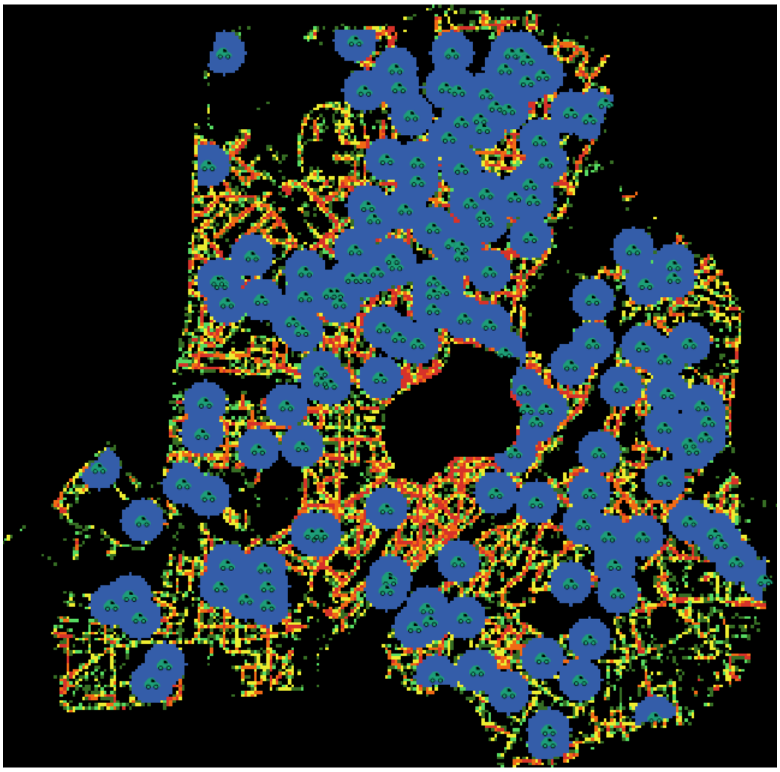


Figure 4.16: Validation: 250m Buffers around Parking Vehicles in Munich in the Simulation Environment

Compared with values of around 4 cars/km^2 which are reality today, some of the simulated values appear very high and lead to so far unknown fleet sizes. It must be kept in mind however, that this dissertation aims to support the diffusion of free-floating carsharing and as initially explained, its positive societal effects can only impact transportation when this innovation comes out of its niche. Potentially, many current car owners might only shift transportation modes when there is a replacement that fulfills their needs for mobility, flexibility, reliability, and safety. If a free-floating carsharing system fails to fulfill this, it will remain niche.

This could be a potential explanation for the success of the concept in Berlin, where three free-floating carsharing systems are offered and in combination, these three systems offer a better spatial coverage than anywhere else.

Moreover, even when there is a – relative to today – high vehicle density of 5-50 cars/km^2, this is still negligible to vehicle densities of private cars which lay in some areas at up to 46,000 cars/km^2 as figure 4.20 indicates exemplarily for Munich. Surely the fleet size will continually increase with a growing customer base but due to its replacement effect on privately owned vehicles; free-floating carsharing will likely

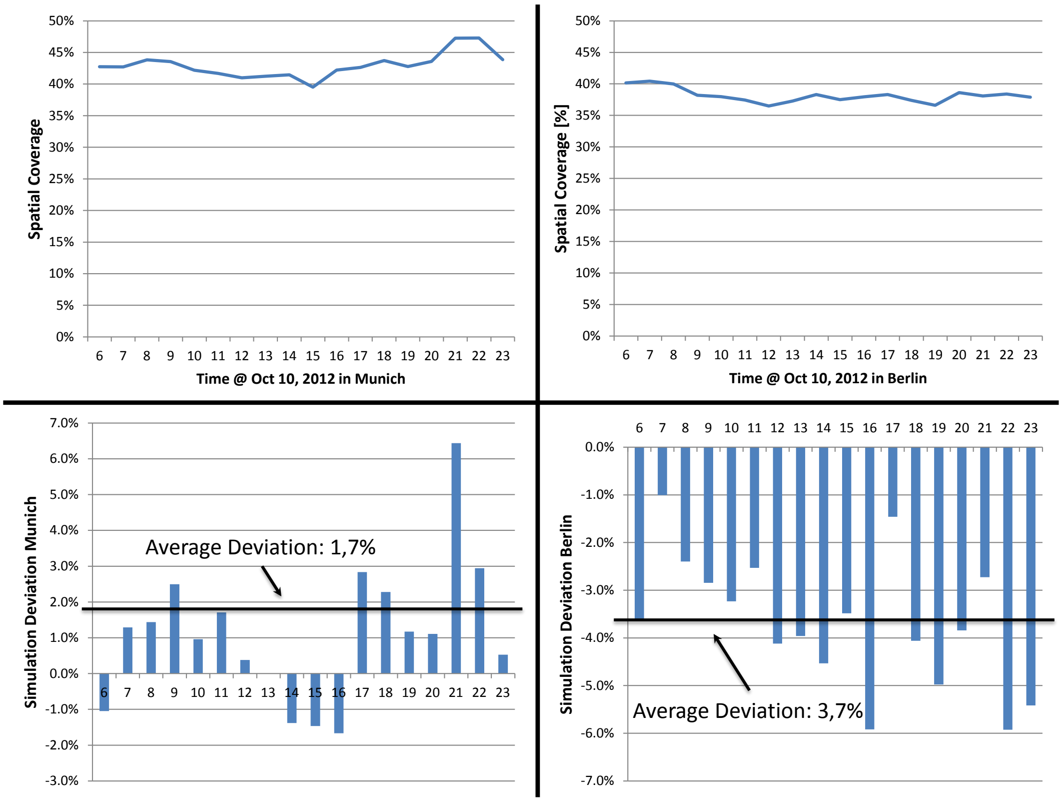


Figure 4.17: Validation: Real World Spatial-Coverage in Munich (Top Left) and Berlin (Top Right) and the Respective Simulation Deviations (Below).

decrease the overall vehicle densities in cities.

As a result, combined with inputs on the respective size of the operating area, the fleet size for any given city can be determined and the following model can be derived:

$$Fleet\ Size = Area\ of\ the\ Operating\ Area[km^2] * Desired\ Vehicle\ Density[\frac{Vehicles}{km^2}]$$

Here, the desired vehicle density is connected to utilization and spatial coverage values that must be chosen by providers. Rather than being expressed by a function, this relationship is manifested in simulation results as described above.

To evaluate this approach with real data is not possible since it has not yet been applied, neither is there data on trials with different fleet sizes in reality as mentioned previously. Furthermore, utilization and technical availability rates are not published. However, it is known that car2go plans to fleet in 4 cars per square kilometer of operating area. [154] In Berlin, the operating area of car2go comprises 275km^2 and the fleet consists of 1,200 vehicles, [43] which results in 4.34 cars/km^2 or 8.5% more than announced. This is a hint that utilization might have been considered, to which extent

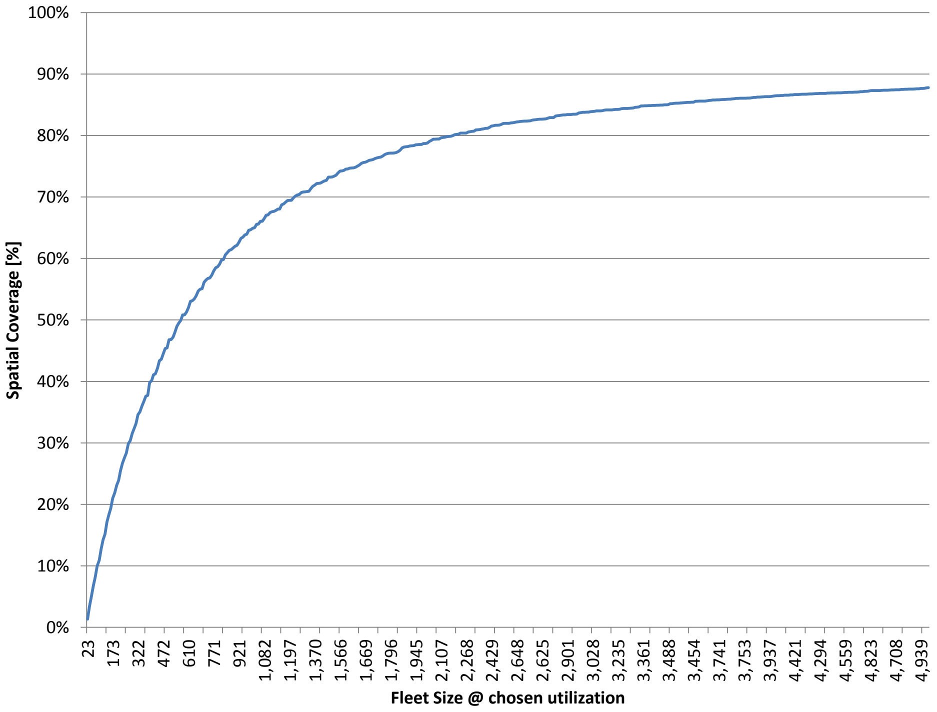


Figure 4.18: The Relationship of Spatial Coverage and Fleet Size (Assumptions: Operating Area: 100km^2, 15% Utilization).

is not clear however. Further, it is also unknown whether spatial coverage is considered by providers or not and it is even less known which service levels are desired.

A validation whether which values for utilization and spatial coverage are ”right” or ”good” is neither possible with empirical data. So far, there have been only relatively minor alterations of the fleet size as well as the fleet size growth went in hand with customer growth. Therefore, it is not possible to measure effects of an increased or decreased fleet size on bookings as well as no saturation (=oversupply of vehicles) could have been observed.

Another approach is to divide a city into zones, continually measure vehicle densities in those zones and see which effects they have on bookings. Again however, no relationships can be found and there is no plateau which would represent a perfect balance of vehicle densities and booking densities in those zones. Figure 4.21 shows this approach based on Munich GPS booking and customer data from October 2012, where Munich was divided in 10 zones (see also figure 4.10).

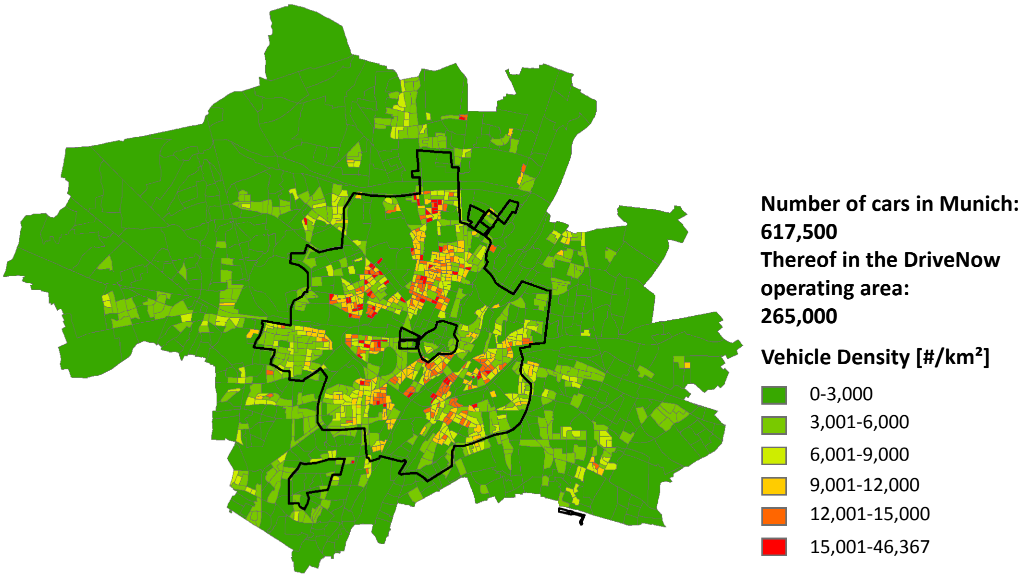


Figure 4.20: Private Vehicle Density in Munich

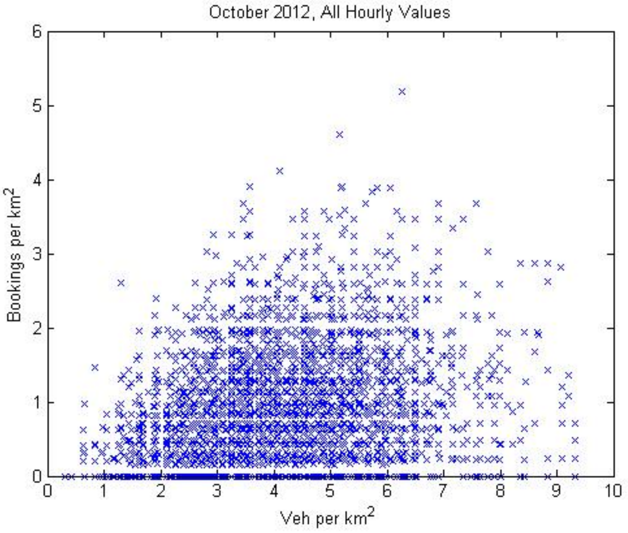
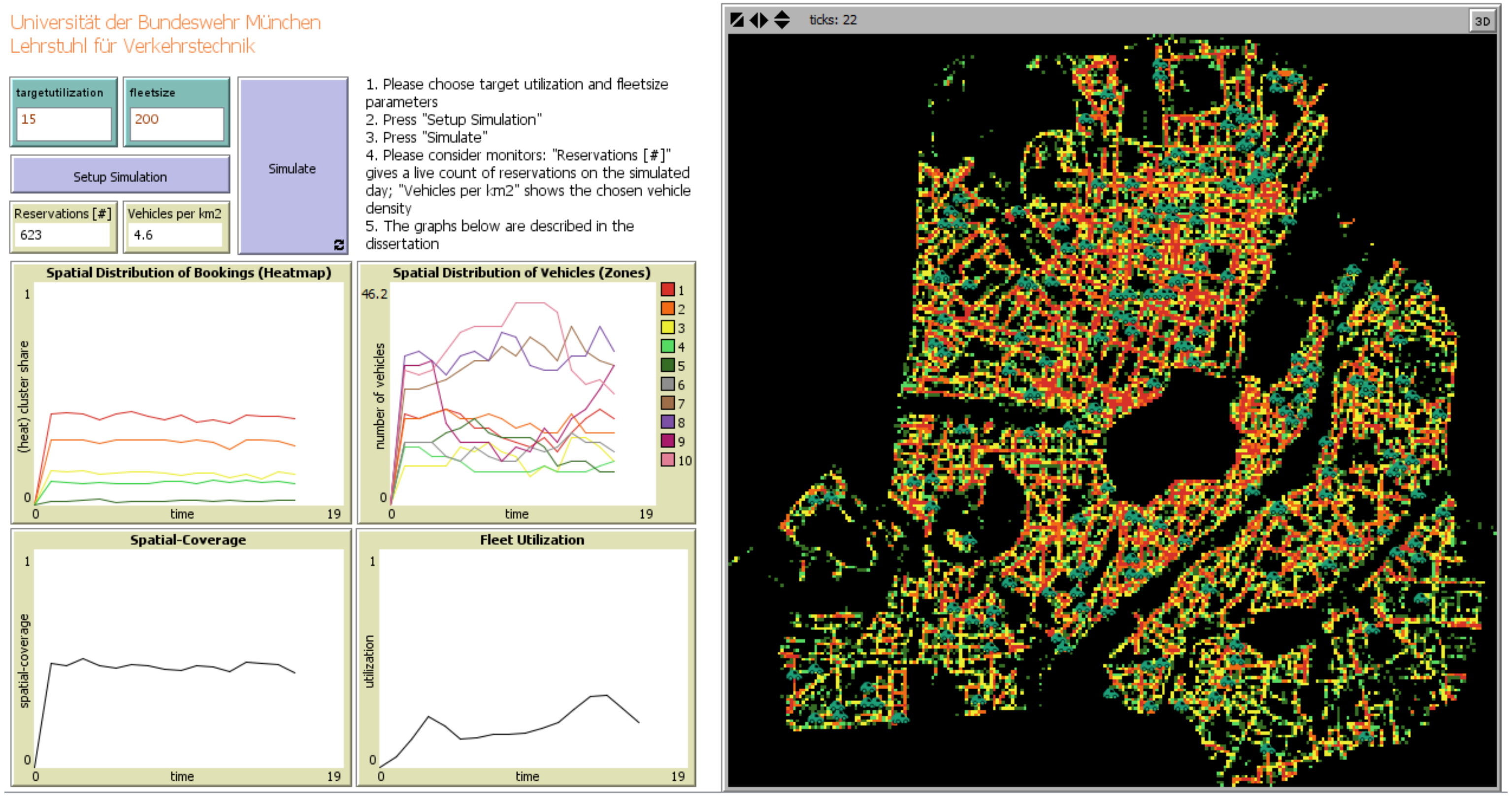


Figure 4.21: The Relationship of Vehicle Density and Booking Density

For the tip of every hour the vehicle density was measured (x-axis) as well as the number of trips that occurred in the following time slice normalized by the area (y-axis). The reasons why there are no results of this analysis are multifarious: First, every zone is different and within a city there are hot- and cold-spots that cannot be compared in their performance. Second, every time of the day is different and at 3:00am not many bookings can be expected regardless of the vehicle density. Third, every day behaves differently, e.g. on Saturdays there are no midday lows. Fourth, also within only one month there is a considerable customer growth which is very hard to incorporate. Fifth, consumer behavior changes constantly as diffusion proceeds. Sixth, there are a variety of technical issues (vehicle problems, data network unavailability) influencing the data that are unknown to the author. Finally and seventh, many other external factors like public holidays, weather, marketing activities, etc. influence booking behavior and therefore the fleet size alone cannot be singled out.

Comparing the same area, at the same time and day requires a long observation period which leads first of all to a relatively small database, falsified trends through seasonal influences, and an even stronger influence through the continually growing customer base. Therefore, also such analyses result in point clouds with no clear relationships similarly to figure 4.21.

Therefore, further trials in reality are necessary to determine which effects an increased availability has on customer behavior. Only through such tests it is possible to evaluate whether the a priori approach developed leads to the desired results and whether the working hypothesis of this approach – an increased availability leads to more bookings – is correct.



targetutilization: 15
fleetsize: 200
Reservations [#]: 623
Vehicles per km2: 4.6

1. Please choose target utilization and fleetsize parameters
2. Press "Setup Simulation"
3. Press "Simulate"
4. Please consider monitors: "Reservations [#]" gives a live count of reservations on the simulated day; "Vehicles per km2" shows the chosen vehicle density
5. The graphs below are described in the dissertation

Figure 4.22: Screenshot of the Developed NetLogo Simulation Tool

4.3.3 Charging Concept

From a local adaptation perspective, carsharing with electric vehicles mainly differs from conventional carsharing inasmuch as there is a need to charge the vehicles. This takes longer than refueling, is potentially more complicated, and must be performed more often due to shorter vehicle ranges. The higher frequency and duration of charging also leads to high operational costs for providers. Depending on the local circumstances, carsharing providers must find the right charging concept because currently there is a very limited charging infrastructure compared to the mature gas station network.

Before examining the charging concept, the underlying technology must be outlined briefly. There are a variety of charging technologies ranging from conductive and inductive charging to battery switch systems. Currently, conductive charging (per cable) is the technological standard and within this technology, there is also a variety of charging modes which are mainly characterized by their charging power and hence charging time. A further distinction can be made regarding the use of either alternating current (AC) or direct current (DC) and single-and three-phase systems. [132] Table 4.6 gives an overview on this matter.

Charging Mode	**Connection**	**Single-phase**	**Three-phase**	**Charging Time**
Mode 1 (AC)	Household socket	Max. 16A 3.7kW	Max. 16A 11kW	2-6 h
Mode 2 (AC)	Charging station, household socket	Max. 32A 7.4kW	Max. 32A 22kW	1-6h
Mode 3 (AC)	Charging station	Max. 63A 14.5kW	Max. 63A 43.5kW	30 min
Mode 4 (DC)	Charging station (fixed cable)	DC-Low max. 38kW		35 min
		DC-High max. 170kW		<15 min

Table 4.6: Charging Modes for Conductive Charging. Adapted from [132]

Based on these different technological solutions, there are also different operational or organizational solutions (charging concepts) for carsharing providers regarding how and where to charge. Here, it must be distinguished between centralized and decentralized charging concepts. [29] Currently, in free-floating carsharing centralized concepts involve charging depots (e.g. parking houses with charging stations) where the provider collects vehicles to charge them, e.g. overnight or when the state-of-charge drops below a predefined number. An example for this is car2go in San Diego where a depot is operated. In this depot, 30 cars can be charged simultaneously. [137] In future, this could furthermore involve charging infrastructure which is installed in company parking houses (being underutilized at night), hotels (being underutilized during the day), shopping centers, park+ride garages, etc. which could enable customer involvement also for central concepts, e.g. in combination with a valet parking service. [29, 205] On the other hand, decentralized concepts already involve the customer who is incentivized to use public (on-street) charging infrastructure when ending a booking as for example it is practice at DriveNow [159] or Multicity [165] in Berlin. Here, charging by the fleet management should be the exceptional case and also relies on decentralized public charging infrastructure.

Charging technology and concept are logically connected. A faster charging technology means higher vehicle availability, lower opportunity costs, but also more infrastructure costs which might not always be necessary, e.g. charging over night when demand is low. This would most likely be the case in most central charging concepts and consequently, mode 1 or 2 technology should be sufficient. This however must be adapted to actual demand as more vehicles would be necessary to compensate charging times in case charging cannot only be performed in times of low utilization. For decentralized concepts carsharing providers will probably not determine the employed technology but rather make use of an existing infrastructure. Investing in an exclusive public infrastructure is economically not feasible and politically unrealistic since the infrastructure would be built on public space. Ideally however, areas with long parking times (e.g. in residential areas at night) would be sufficiently supplied by mode 2 charging technology whereas in booking hotspots or areas with a quick turnover (highway rest stops, shopping centers, restaurant areas, traffic hubs) mode 3 or 4 might be economically feasible. [205]

Having laid this background, carsharing providers must adapt their charging concept to the given environment to ensure the optimum of customer comfort and reasonable efforts (hence: costs) for the provider. Ideally, customers do not want to have any hassle and simply leave the car wherever they want without performing any duty. The ideal world from a provider's point-of-view is the contrary, customers charge the vehicles regularly themselves and no expensive fleet management action is needed.

Combining both ideals could work best in an environment with a high number of publicly available charging stations. Customers could still go to their desired destination and the parking space in front of the charging station could be reward enough to compensate the effort for plugging in the vehicle. Thus, the potentially disadvantageous charging process is cost neutral for customer and provider and might even be attractive and beneficial for the customer in areas with otherwise high parking pressure. Furthermore, centralized charging is potentially disadvantageous for providers as they have to invest in depots, charging technology, and fleet management to realize the concept. Moreover, each time a vehicle has to be charged, variable costs occur since the vehicle has to be driven to and from the depot. Also in case the customer is incentivized to bring the vehicle to a depot, which might be shared with other institutions to keep investments low, this is still more expensive as the incentive must be higher to convince customers to perform the transfer drive to a depot or to go to a depot to pick up a vehicle rather than simply take a vehicle from the street. Furthermore, the necessary transfer from and to the depot also limits availability and hence increases the fleet size.

Different from the operating area or the determination of the fleet size, the charging concept does not need to be optimized according to a success indicator since there are only two options (central/decentralized) with a clear preference to decentralized charging since it fits customer and provider needs best.

However, it might not always be possible to employ decentralized charging. The consideration above shows that the environment/city must have a sufficient charging station density, which depends on the area of the operating area and the number of charging stations that are contained in it.

Another potential local influential factor is the respective employed charging technology. Up to now, public infrastructure almost exclusively consists of mode 2 chargers and providers do not have many choices to adapt to local technology. In future however, mode 3 and 4 technology will surely diffuse and become a part of public charging infrastructure. Ideally, these chargers are placed according to the previous discussion - slower charging at locations where cars naturally park longer, fast charging in hot-spots. Here, the technological effect that more vehicles can be charged (as quicker chargers are employed) in areas with higher demand (hot-spots) leads to the conclusion that ideally the infrastructure should be distributed evenly in the operating area to ensure flexibility and proximity to customers' destinations.

An influential factor for the choice of the charging concept that does not depend on local circumstances is the chosen incentive strategy. Even if there is only a limited charging station density, high incentives might encourage people to detour and to utilize stations so much, that the charging challenge can be solved. Experience with gasoline vehicles shows that there are also people who deliberately pick up cars with low tank levels to fuel them up and get the incentive. Whether this is a meaningful solution for providers depends on their individual cost structure and whether it is cheaper to incentivize customers or to transfer vehicles on their own. This strategic decision does not depend on local circumstance and is therefore not further considered in modeling.

A consequence from this consideration is that station-density is the clear influential factor whether (and to which degree) decentralized charging concepts can work. If a city offers a sufficient density, providers should employ a decentralized charging concept or at least make use of the public charging infrastructure as much as possible (e.g. car2go in San Diego incentivizes users to use public chargers and only charges in its depot when needed similarly to DriveNow in Munich which incentivizes the use of the merely 8 stations in its operating area). If there is no sufficient public charging infrastructure, central concepts must be applied. A ”sufficient” public charging infrastructure however will only be deployed if there is a ”sufficient” amount of electric vehicles utilizing them. This chicken and egg problem is seen as one of the main obstacles of electromobility. [190] It must be noted however, that a carsharing provider who potentially brings hundreds or thousands of electric vehicles to a city might take an active role in solving the problem and might thus change the environmental settings actively and be (one of) the reasons why more public chargers are installed.

In a next step it must be determined what a ”sufficient” charging station density is. The term is defined as follows:

$$Station\ Density = \frac{Number\ of\ Public\ Charging\ Stations}{Operating\ Area}$$

Here, the operating area is determined through the model in subsection 4.3.1 and clearly stands in a qualitative interrelationship to the existing infrastructure but is defined as given for this investigation. The missing part of the equation is the number of charging stations.

Similar to the determination of the fleet size, the ideal number of charging stations in the operating area depends on the willingness to walk. As a rule of thumb, also here the 250m-500m beeline applies (see subsection 4.3.1) as the distance people are willing to walk to a car should a priori be the same as the distance they are willing to walk from a car (parked at the charging station) to their destination. The pessimistic assumption that people are only willing to walk a 250m beeline equates to 5 charging stations per square kilometer similarly to the willingness to walk to a car. On the other hand, an optimistic 500m beeline equates to 1.3 stations/km^2. Given the fact that people might get incentivized through money or a free parking spot, this research tries to strike a balance and 3 charging stations/km^2 are suggested to be sufficient. Of course however, this will differ from person to person, weather conditions, and the individual situation.

Additionally, utilization and technical availability of the charging stations are potential factors in future, when there will be more electric vehicles on the street. Currently, the utilization of the existing infrastructure can be neglected since there is a limited number of electric vehicles, privately owned BEVs are mostly charged in private garages at the owner's home, charging stations mostly have two or more parking slots and charging possibilities per station so that two cars can charge simultaneously, and averagely utilized carsharing vehicles must only charge every second day in average. Therefore, the required number of stations can be limited to the spatial factor that people want to charge close to their desired destination. Another argument is that in the case that a vehicle has a very low state of charge (SOC) and charging becomes mandatory for the customer (e.g. SOC $<20\%$), it cannot be demanded from a customer to go way of his desired destination as this would be inexpedient to the concept. If this was the case, people would avoid cars with a low SOC. This results basically in a lower vehicle availability and utilization and thus must be strictly avoided. However, if customers do not want to charge, fleet management must do so which is costly and even more costly if the charging station density is low (longer transfer drives, occasional towing might be needed).

From this perspective, charging stations should also be equally distributed within the operating area to ensure a basic coverage. Even though bookings appear to have clear hot-spots, this inequality should rather be answered by the respective charging technology than with more charging stations. To charge slowly at hot-spots will limit availability or, alternatively, will lead to minimal improvements of the state-of-charge when customers are allowed to unplug charging vehicles.

As a result of this discussion, the theoretically deducted number of three charging stations per square kilometer in the operating area should be the threshold value or tipping point for the decision whether to employ a decentralized or central charging concept:

$$Station\ Density = \frac{Number\ of\ Public\ Charging\ Stations}{Operating\ Area} \geq 3\frac{stations}{km^2} \Rightarrow Decentralized$$

$$Station\ Density = \frac{Number\ of\ Public\ Charging\ Stations}{Operating\ Area} < 3\frac{stations}{km^2} \Rightarrow Central$$

As discussed, these stations should use the appropriate technology depending on their location as well as their spatial distribution should be ideally equal in the operating area. Therefore, the location of charging stations and their employed technology should be qualitatively included in the choice of the charging concept as well as in the decision of where to define the business area (see discussion in subsection 4.3.1).

The qualitative check can rely on the output of the regression model that aids in determining the operating area. In expected hot-spots there should be faster chargers than in areas where less bookings and longer parking periods can be expected. In case the employed technology is regarded as suitable, the spatial distribution of charging stations within the operating area should be equal to ensure proximity. If the charging technology does not fit this prescription, potentially more chargers are needed in areas with longer parking durations. In practice, a visual check of chargers' spatial distribution can be regarded as most useful. Figure 4.23 gives an overview on different methods to carry out this check. Map a) shows the spatial distribution of RWE charging stations in Berlin within the operating area of DriveNow. Here, it can clearly be seen that stations are clustered and that there are wide areas within the operating area that are not covered by RWE's network. To extend this visual check, the use of geographic information systems (GIS) can provide for a more detailed analysis. Map b) shows the application of the standard distance to the Berlin data. This statistic provides a summary measure of charging station distribution around their center. This is similar to the way a standard deviation measures the distribution of data values around the statistical mean. Here a circle polygon is drawn centered on the mean and with a radius equal to one standard distance, covering ca. 68% of all stations. Another way of using a GIS to measure and depict spatial distribution is the standard deviation ellipse as illustrated in map c). It summarizes the spatial characteristics of geographic features such as central tendency, dispersion, and directional trends. Charging stations are concentrated in the center with fewer features toward the periphery and one standard deviation ellipse polygon will cover approximately 68 percent of stations as well. [73] A third and pragmatic approach is to draw buffers around charging stations that represent the 325m walking circle (= 3 stations/km^2) beeline radius that is assumed to be regarded as acceptable for walking to and from a charging station. This is shown in map d). These buffers show the potential ”commuter belt” around stations and are therefore useful when checking the coverage and potential gaps in the spatial distribution of charging stations.

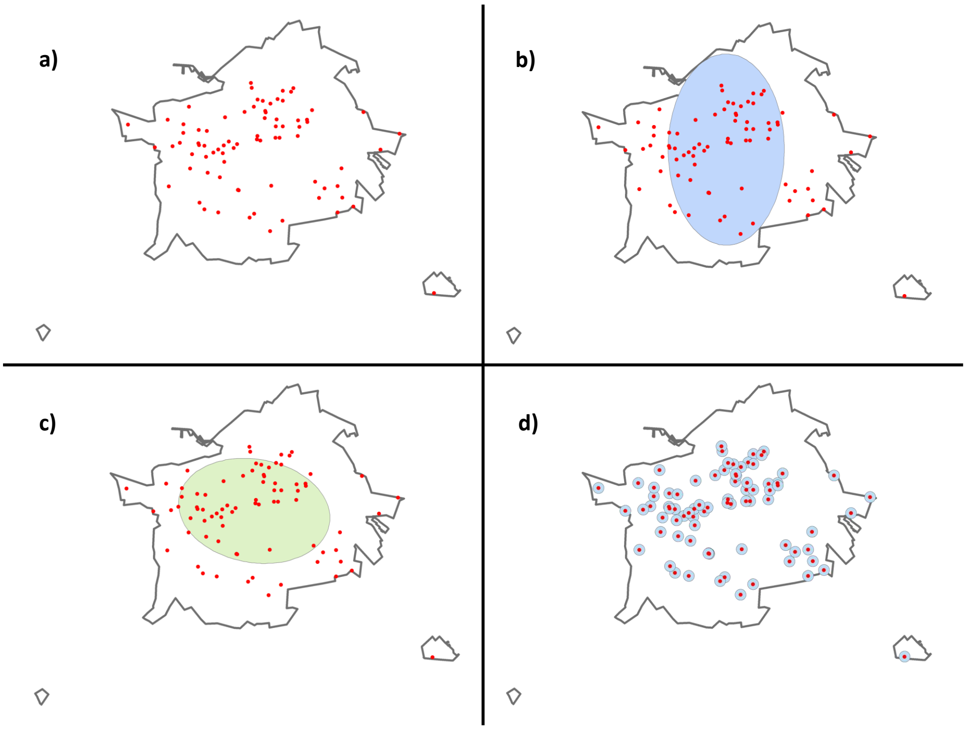


Figure 4.23: Overview on Methods to Check the Spatial Distribution of Charging Stations: a) Shows a Simple Map of RWE Charging Stations in the Operating Area of DriveNow Berlin for Visual Inspection, b) Applies the Standard Distance, c) the Standard Deviation Ellipse, and d) Walking Circles with 325m Beeline Radii

A third option for analyzing and measuring the spatial distribution of chargers is to rely on index values. This however is not recommended and it is crucial to perform a qualitative visual check because merely relying on index values (e.g. when no graphical GIS system is available) could easily lead to misinterpretations. For example, Huang and Leung showed that the Coefficient of Variation and the Hoover Concentration Index are different kinds of measurement intended to show the same pattern of regional inequality but they may show opposite results when they are applied to specific cases. [115]

Since operability is a requirement of the model-based framework, the use of a GIS should be avoided when this does not compromise the performance of the framework. Without doubt, the use of a GIS as applied in map b), c), and d) in figure 4.23 can support decision makers but a simple visual check as in map a) will also enable managers to make decisions. As a consequence no statistical measures for geographic distribution are incorporated in the model-based framework. Nevertheless, this section showed how to quantify the spatial distribution and it is left to the readers' discretion whether to perform a statistical analysis in addition to the visual check of the spatial distribution of charging infrastructure or not.

Lastly, it must also be considered that the choice of the charging concept might have effects on the fleet availability (cars are utilized for different time periods whilst charging) and hence on the fleet size as discussed in the previous section. Also, in this concept, the utilization of charging stations and thereby the possibility that some stations are occupied and not available is neglected for the reasons discussed. In future however, BEVs could reach significant market shares. In this case, the necessary number of charging stations for decentralized charging concepts can be derived similar to the number of vehicles and the utilization of the given stations by all vehicles must be considered.

To evaluate this proposition with empirical data, current free-floating operations with electric vehicles are considered. Since the biggest provider, car2go, does not publish where and how many charging stations are part of the service in the respective cities, multiple sources were used in the desk research conducted. Table 4.7 gives an overview on the results.

It can be seen that only on two occasions charging depots are in use (at least according to the communication made by the firms). One time, in San Diego, they are used in combination with a decentralized concept as fall back solution. The other time is in combination with a few public chargers to enable customers to charge themselves occasionally. Furthermore, a clear relationship between the willingness to employ electric vehicles in free-floating carsharing operations and station density is revealed. Operators seem to avoid central concepts and are only deploying substantial electric fleets where there are relatively high charging station densities. Additionally, in these four cites the local government or the local charging infrastructure providers are planning to expand the charging network extensively: Berlin announced a tender with the aim to employ 300 charging stations by the end of 2013 and 800 by the end of 2015, [211] in Stuttgart the expansion of the charging network to 500 stations is planned in the course of 2013, [72] Amsterdam announced to install 1,000 charging stations in 2012 (result unknown), [138] and San Diego is in the process of installing 700 charging stations within the city limits. [106] From this it follows that current station densities in these cities will increase remarkably shortly after the start of operation of carsharing

Provider	**City**	**Charging Concept**	**Operating Area [km^2]**	**Fleet Size (BEVs)**	**No. of Charging Stations**	**Charging Station Density** $\frac{Stations}{km^2}$	**Vehicle Density** $\frac{Vehicles}{km^2}$
car2go	Ulm	Decentralized	52	300 (20)	48	0.92	5.77
car2go	San Diego	Mixed	77	300 (300)	100	1.29	3.9
car2go	Amsterdam	Mixed	80	300 (300)	250	3.13	3.75
car2go	Stuttgart	Decentralized	75	300 (300)	190	2.53	4
car2go	Portland	Central	95	280 (30)	4	0.04	2.95
Drive Now	Berlin	Decentralized	140	650 (40)	64	0.46	4.64
Drive Now	Munich	Central	73	300 (20)	8	0.11	4.11
Multicity	Berlin	Decentralized	107	350 (350)	63	0.59	3.27

Table 4.7: Overview of Free-Floating Carsharing Offers Regarding their Charging Concept and Local Charging Station Densities (At the Start of Operation, where Data was Available). Based on: [137, 111, 244, 177, 138, 162, 145, 42, 44, 70, 159, 165, 164].

offers and thus, comes close or even higher than the theoretically deducted number of 3 charging stations per square kilometer as a necessary basic coverage to allow for decentralized charging concepts.

Looking at current practices, it seems that providers avoid central charging concepts and rather employ conventional fleets. However, if providers decide for strategic or political reasons to employ electric vehicles in a city with an insufficient charging station density, central charging concepts are the agony of choice.

4.3.4 Fleet Mix

The next aspect that has to be modeled is the fleet mix. The fleet mix can be seen regarding different types of vehicles (compact cars for the city, minivans for transporting bulky items, convertibles for vacation trips, etc.) as well as regarding to different drivetrains (electric cars for short and conventional cars for long distances).

Offering a variety of vehicles gives customers the possibility to choose the right vehicle for a variety of use cases. Ideally providers should offer a wide variety of different vehicles in every city and therefore the mix of different types of vehicles is not directly influenced by local circumstances. However, an aspect that should be considered qualitatively is the existing local vehicle mix. For example, in Dubai or Los Angeles large vehicles shape the streetscape whereas in Italy small city cars are predominant. The reason for this might be cultural, economical (different fuel prices), but also due to local infrastructure (street widths for example). Therefore, the per se standardized fleet mix of different vehicle types might need to be aligned according to local circumstances if there is an extreme misfit and customer acceptance is thought to be jeopardized. To the contrary, providers so far do not adapt their vehicle mix to local circumstances. Whilst DriveNow offers different vehicle types in its fleet, it does not alter its offer market by market. Car2go goes one step further and only offers one type of vehicle regardless of the market. This vehicle, a Smart, which is a two-seater micro-car, is built for urban use, compact in size, and environmentally friendly and therefore an ideal car for free-floating carsharing according to car2go. [59] This approach is not only taken to cities where such vehicles are common, but also to cities like Denver and possibly even Los Angeles [48] in future where large vans or trucks are standard. The reason for neglecting this aspect might lie in customers' perceptions. A small survey among customers from DriveNow in Germany (n=38) asked according to which factors people choose a carsharing vehicle. The answers were very conclusive, since 95% stated that the location of the car is important, whereas only 27% are interested in the type, 16% in the brand, and 5% in the engine power of the vehicle. [21] Nevertheless, ideally a qualitative alignment to the local vehicle mix should be carried out in order to avoid misplanning.

As discussed in section 3.2, the local adaptation of the fleet mix focuses on the mix of drivetrains and hence the share of BEVs in local carsharing fleets. Discussing what a suitable success measure for the fleet mix is, is not relevant, because the fleet mix strongly depends on the results from the charging concept model (see subsection 4.3.3). Applying a fleet mix model only becomes necessary when a sensible charging concept can be applied. This means if it is not possible to charge decentralized in a city, the use of electric vehicles should be avoided because central charging concepts are disadvantageous for customers and providers as discussed previously. This is also mostly the case in reality where electric fleets are the exception in free-floating carsharing.

Regardless of the charging concept however, a further possibility for the need of BEVs in the fleet mix could stem from regulatory circumstances or strategic decisions. For example, some cities like London charge inner city tolls from which electric vehicles are exempt. Depending on the respective costs and circumstances, it might be sensible to infleet BEVs even though there are not enough public charging stations to employ a decentralized charging concept. Another scenario could be a city that only issues parking licenses to carsharing providers with electric fleets. Not only regulations but also a company's strategy might urge the need to employ BEVs. For example, automobile manufacturers that are also carsharing providers might decide to support the compliance to CO_2 regulations or to promote electromobility in a market with the help of electric carsharing fleets. Such decisions will require an alignment to the decision on how to shape the fleet mix. In case such a regulatory or strategic target is set, this also directly determines the share of BEVs in a fleet.

As a consequence, the model for determining the fleet mix only applies when the charging concept was determined to be decentralized. In this case, BEVs should be the prevailing part of the fleet mix since the concept of E-carsharing offers various advantages from an adoption perspective as outlined in section 2.3. Electric vehicles are optimal vehicles for inner city traffic and hence appropriate for most use cases in free-floating carsharing and modeling their share in the fleet mix targets again the maximization of customer acceptance.

For other use cases, where longer ranges are needed, conventional gasoline or diesel vehicles should be available. Looking at the distances a vehicle covers per day; it becomes apparent that only in 1.43% of all days a vehicle drives more than 150km per day which is currently a common range of BEVs. This distribution of cumulated vehicle trips per day can be found in the histogram in figure 4.24 and relies on GPS booking and customer data from Berlin and Munich from 11/2011 - 10/2012 where only bookings $\geq$ 1 min and $\geq$ 1km (n= 627,681) are considered. However, looking at trips only on a day to day basis might be misleading since long-distance trips might be longer than a day or last overnight. To consider this aspect, a second analysis is carried out using the same data. Assuming a vehicle range of 150km, an average state-of-charge of 50%, and a buffer of 10km, every trip $\geq$ 65km must be carried out with a conventional vehicle. In reality, such trips only account for 1.16% of all bookings as depicted in figure 4.25.

To serve these 1.16% of all cases, conventional vehicles are needed. It is not sufficient however, to simply infleet 1.16% of conventional vehicles because a longer

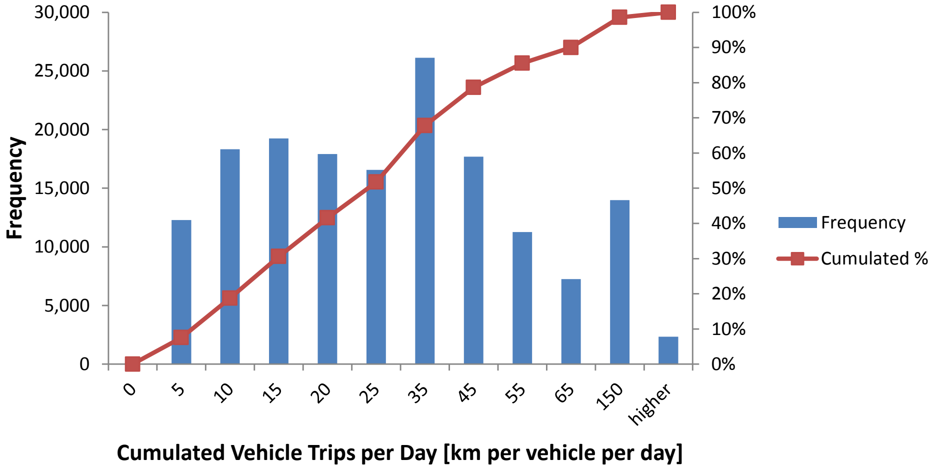


Figure 4.24: Histogram on Vehicle Kilometers per Day

distance trip also takes more time and therefore limits the availability of the few conventional vehicles. Whilst the average booking duration of the 98.84% of bookings that can be served with electric vehicles is 32.1 minutes, the average booking duration of trips with 65km or more driving distance is 290.5 minutes. This means a trip that can only be served with a conventional vehicle is in average nine times longer than a trip that can be served with an electric vehicle. From this it follows that the minimum share of conventional vehicles should be set accordingly:

$$\mathit{Minimum\ Share\ of\ Conventional\ Vehicles} = 1.16\% * \frac{\mathit{290.5\ minutes}}{\mathit{32.1\ minutes}} = 10.5\%$$

To get to one of this 10.5% minimum share of conventional vehicles it is mostly necessary to walk longer than five minutes. It is assumed however, that this is accepted by customers since the longer walk is negligible in comparison to the expected longer overall duration of the conventional vehicle trip as opposed to the average of 30 minutes driving time for BEV trips. Despite this assumption, people will not be willing to walk longer in proportion to their trip time as this would be in average 9 x 5 minutes = 45 minutes. In this case, it is still possible to use an electric vehicle to drive to the required conventional vehicle. This possibility should be enabled by providers, e.g. through the possibility of double-reservations, to compensate the relatively low density of conventional vehicles.

As mentioned in the discussion of the charging concept in subsection 4.3.3, ideally, customers do not want to have any hassle and simply leave the car wherever they want without performing any duty. Providers on the other hand aim that customers charge the vehicles regularly themselves and no expensive fleet management actions

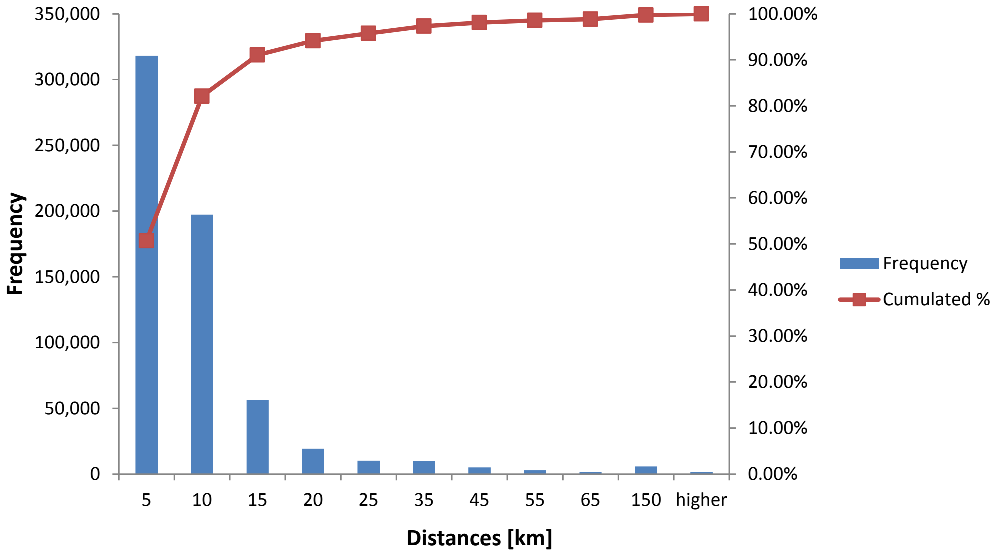


Figure 4.25: Histogram on Trip Distances

are needed. Combining both views is concluded to work best in an environment with a sufficient number of publicly available charging stations. Here, potentially available parking spaces at these stations might even outweigh potential hassles when charging the vehicle. A sufficient number of charging stations to charge decentralized was defined to be three stations per km^2 in the operating area due to the limited willingness to walk. When looking at the influential factors for determining the fleet size in section 4.3.2, it becomes clear that there are more cars than the minimum number of charging stations, depending on the utilization and spatial coverage rates set. This number of electric vehicles cannot be chosen arbitrarily high. The utilization of charging stations through carsharing and other electric vehicles is already factored out since vehicles do not need to be charged after every trip and there are not many electric vehicles in the markets yet. In order not to overwork this assumption when infleeting high numbers of BEVs, the maximum number of BEVs should not be higher than the number of charging stations in the operating area.

From this discussion, the following model can be derived:

1) If there is a decentralized charging concept, then:

$$\frac{Number\ of\ Charging\ Stations}{Fleet\ Size} \geq 89.5\% \Rightarrow 89.5\%\ BEV\ share$$

$$\frac{Number\ of\ Charging\ Stations}{Fleet\ Size} \leq 89.5\% \Rightarrow BEV\ share = \frac{Number\ of\ Charging\ Stations}{Fleet\ Size}$$

2) If there is a "Strategic/Regulatory Need for BEVs", then: *Manual Input*

3) Else: $0\%\ BEV share$

An evaluation of this model is not possible since it is not known how operators determine the mix of electric and conventional vehicles. Only from DriveNow it can be assumed that the number of electric vehicles is relatively low, as the vehicles are used in research projects as well as the vehicle itself is only a prototype, accordingly, equipping the whole fleet would not be feasible. Car2go and Multicity on the other hand appear to fleet in vehicles strategically determined since they either have completely electric fleets, e.g. to get access to a city's parking spaces, or just a handful of BEVs, e.g. for promotion reasons. Multicity for example clearly positions itself in the market as purely electric offer; hence the question regarding the fleet mix is irrelevant for them. Table 4.7 gives an overview on the fleet mix of all at least partly electric free-floating systems. Nevertheless, from a theoretical perspective the proposed model is seen as robust whilst in reality regulatory or strategic reasons will often play a role when determining the fleet mix. This is also considered by the model by allowing for manual input.

4.3.5 Pricing

Determination of the Willingness-to-Pay

When modeling the price, it is aimed to support decision makers in setting an appropriate price level and adapt this level to local conditions.

In Germany, free-floating carsharing was born and is in operation since 2008/2009 when car2go started testing the approach in Ulm. Since then, different prices were tried out and the driving price per minute of car2go reached a plateau of 0.29 EUR. [231] This was also the price when DriveNow, the second free-floating provider, started operations in 2011 until changing the price in 2013 to 0.31 EUR per minute [69] whilst offering only well-equipped premium BMW and MINI vehicles as opposed to car2go's base Smart vehicles. Because customer growing rates continue to be very high, a price around 0.30 EUR per minute appears to be acceptable in Germany from a diffusion and customer perspective. Whether this price point is at its optimum must be questioned however.

Ideally, prices are set with the knowledge of their elasticities, i.e. how much more or less bookings can be expected when the price is altered. Unfortunately, there is no available data on different price points and the effect on the system. Also, price elasticities of other products from the transportation sector cannot easily be transferred since the innovation of free-floating carsharing is a new and different way of transportation. Accordingly, simply transferring other price elasticities might lead to wrong conclusions and no evaluation would be possible in this research. This makes a slightly different approach necessary.

If observation is not possible, survey-based methods appear as alternative for measuring willingness to pay. [163] For this dissertation, van Westendorp's Price Sensitivity Meter (PSM) [245] is chosen because it appears as most practicable and useful technique. Whilst its hypothetical character can be criticized for leading to potentially unrealistic results, the observation of real transactions would always be under the influence of the existing market price and therefore, results cannot be generalized. Also, their potential cost is out of scope of this research. A further advantage of the PSM is that it can be applied through online-surveys and is relatively compact, for which reason it is possible to achieve high participant numbers and thus a better representativity of results.

To give a brief overview on the technique, the PSM consists of four basic questions which are answered by the respondents referring to a scale of prices:

1. At which price on this scale are you beginning to experience carsharing as cheap?
2. At which price on this scale are you beginning to experience carsharing as expensive?
3. At which price on this scale are you beginning to experience carsharing as too expensive - so that you would never consider using it yourself?
4. At which price on this scale are you beginning to experience carsharing as too cheap - so that you say "at this price quality cannot be good"?

In the actual survey, for which 2,500 random customers in five cities (=12,500 customers in total) were asked in May 2014 via email to fill out a online survey, "carsharing" is of course altered to the product name and moreover, a scenario is created which mirrors typical usage patterns and is therefore tangible for customers. This scenario 1 contains a city-specific use-case where a customer drives 30 minutes to a park and picks up some drinks on the way. This is followed by the four questions of the PSM in which a total price for this drive is the reference point. With this design of the questionnaire, it is tried to make customers forget the actual minutely price and think about how much they would pay for such a trip.

For comparison and opposed to this approach, scenario 2 is developed, which directly asks customers about their opinion on the minutely driving price, which is relatively abstract but useful for comparison with results from scenario 1, especially when considering the communicative aspect of a single minutely price. In order not to distort results, it was blocked to go back to scenario 1 once answers were submitted to prevent customers from aligning answers.

As a result, 2,071 customers participated in the survey. Data was cleared for incomplete answers and bad data, e.g. when a customer states a higher price for ”cheap” than for ”expensive”. This leaves 1,653 complete and valid answers. Analysis shows that 53% of respondents were female and 41% also used another free-floating carsharing provider and due to this and the random choice of customers, data can be regarded as transferable for other providers as well.

Following van Westendorp’s guideline on analysis and interpretation [245], the four questions asked in each scenario yield four cumulative distributions which are depicted schematically for scenario 1 in figure 4.26. In this graph, the x-axis represents the different price points whereas the y-axis shows the cumulative number of customers (=potential market share). The answers of the respondents are shown as cumulated frequency distributions whilst three curves are depicted inverted to be able to deduct some key information graphically. This includes:

- **Optimal Pricing Point (OPP):** An equal number of people believe a product is too cheap or too expensive; hence, resistance against this price is very low (intersection of ”too expensive” and ”too cheap” (inverted)).
- **Indifference Price (IDP):** An equal number of people experience the product as cheap or expensive (intersection of ”expensive” and ”cheap” (inverted)). This is generally the median price actually paid by the customer or the price of the product of an important market leader.
- **Point of Marginal Cheapness (PMC):** The number of people that experience the product as too cheap is larger than the number which experience it merely as cheap (intersection of ”cheap” and ”too cheap” (inverted)).
- **Point of Marginal Expensiveness (PME):** The number of people that experience the product as too expensive is larger than the number which experience it merely as expensive (intersection of ”expensive” and ”too expensive” (inverted)).
- **Range of Acceptable Prices:** The range between PME and PMC, because below or above these points prices are unacceptably cheap or expensive for most people.

For reasons of clarity, the results of graphical analysis with the explained relevant pricing points determined are extracted in table 4.8. Furthermore, as figure 4.26

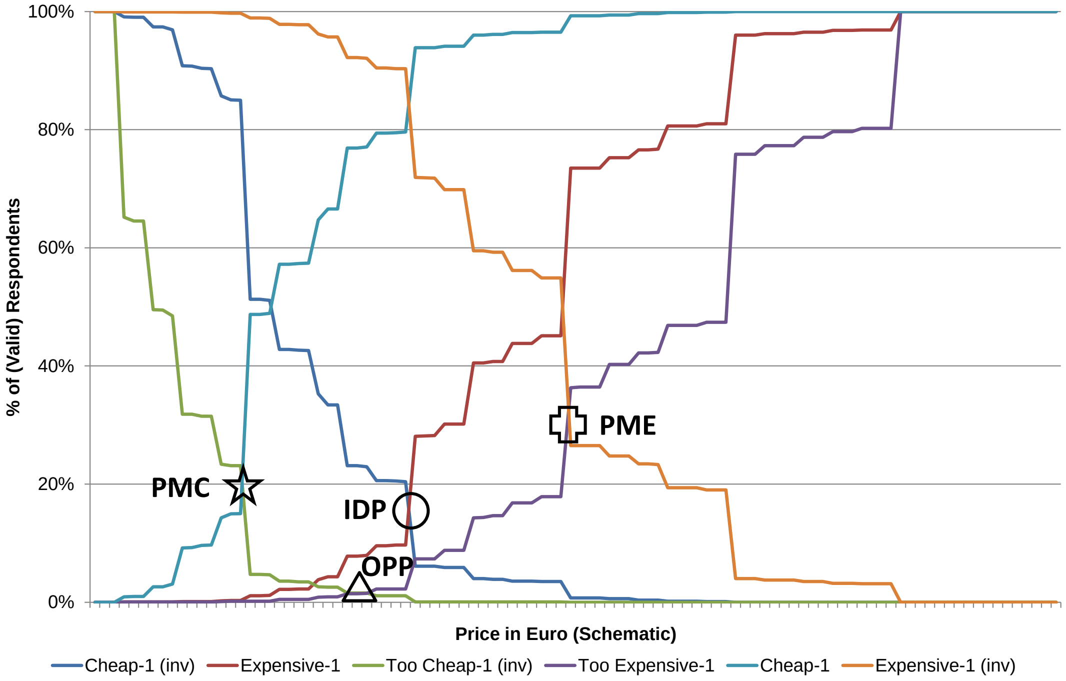


Figure 4.26: Price Sensitivity Meter Scenario 1, All Groups

shows, customers have a very ”sharp” price-consciousness due to the low indifference-percentage (15% in scenario 1 vs. 5% in scenario 2). Nevertheless, scenario 1 and 2 come to different results as expected. Both, OPP (27 vs. 19 cent) and IDP (33 vs. 24 cent) are significantly lower in scenario 2, which can probably be accounted to the fact that respondents are well aware of the current minutely price and their answer might be tactical in order to influencing future pricing decisions. This comparison however reveals the high value of scenario 1, where such tactical behavior appears less likely due to the veiled questioning and therefore, analysis results can serve well for pricing decisions. Furthermore, based on this comparison providers might be urged to change their communication. Communicating specific use cases might lead to higher price acceptance as sensitivity for the often communicated minutely price seems higher.

For the reasons given and due to the fact that scenario 1 comes very close to actual market prices, solely scenario 1 is used for deeper analysis which is carried out in three steps.

First, potential differences between cities must be analyzed as this could give valuable insights for local adaptation. Accordingly, scenario 1 was designed city-specific (individual use cases) and since an equal number of customers was addressed in each of the five cities analyzed, a representative dataset for each of the cities was derived as figure 4.27 shows.

Second, also the age might reveal interesting results. Figure 4.28 plots the age distribution of customers in the analysis with a medium age of 35. Following the hypothesis that older customers have higher incomes, analysis might also reveal a different willingness-to-pay for different age groups.

Third and finally, also different usage frequencies might reveal differences in willingness to-pay since currently too high prices might obstruct customers from using the system more frequently. Figure 4.29 shows that analyzed customers have very different usage patterns which allows for this analysis.

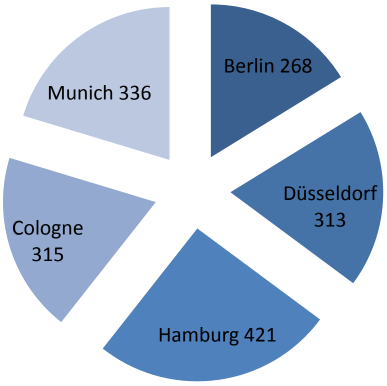


Figure 4.27: Survey Answers per City, Total n = 1,653

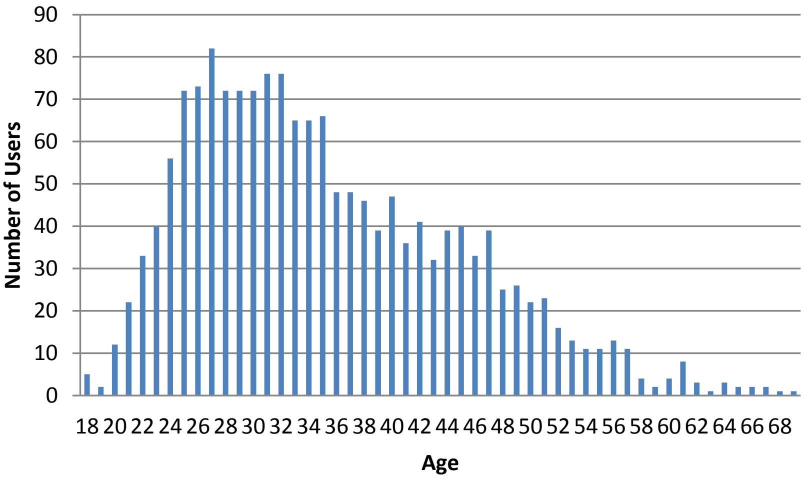


Figure 4.28: Age Distribution of Analyzed Customers

Comparison in table 4.8 shows, that the willingness-to-pay does not vary much between the analyzed cities even though general purchasing power varies e.g. between Berlin and Munich. This result underlines again that prices should be adapted on a national but not on a city level.

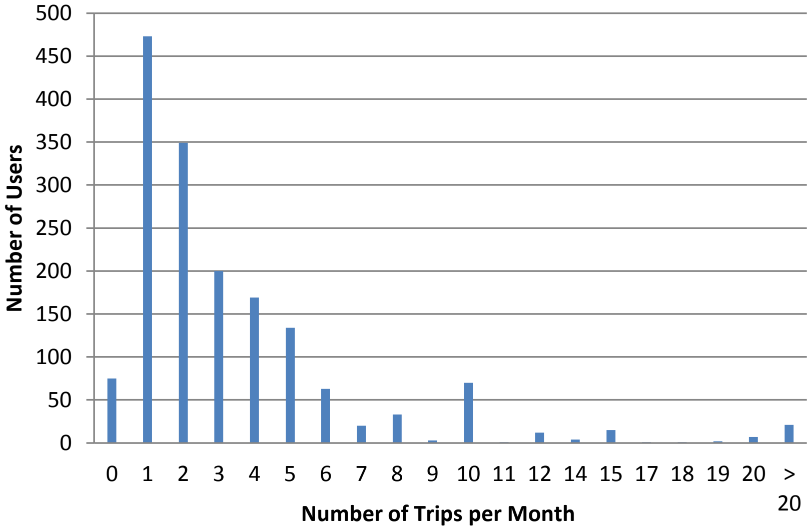


Figure 4.29: System Usage of Analyzed Customers

Similarly, there is no big difference in price sensitivity when comparing older and younger customers. The hypothesis that older customers have better incomes and are willing to pay more must be rejected since the opposite is true, younger customers under 25 years (mostly students and potentially low earning young professionals) are even willing to pay slightly more for the service.

Lastly, analysis regarding the system usage of customers reveals indeed that the OPP of heavy users is 5 cent higher than that of light users but the IDP and the range of acceptable prices is identical for both groups. Therefore, price might be a reason for little usage of carsharing but the small differences hint that this might not be the main reason.

In summary, the determination of the willingness-to-pay revealed interesting results, especially analysis results from scenario 1. It is shown that different groups in respect to different cities, ages, and usage frequency, do not show substantially different price perceptions. This makes the analysis results even more generalizable and powerful. When it comes to local adaptation of the price level in a next step, it is up to the decision maker to rely on the current market price of 0.30 EUR per minute as base price or to choose a different base price based on the price sensitivity analysis results above. This decision might depend on the competitive situation and the individual cost base of a provider, e.g. when a lower price and therefore more customers help to maximize the contribution margin, a lower price can be economically feasible.

Scenario	Group	OPP	IDP	PMC	PME
Scenario 1	All	27	33	16	49
Scenario 2	All	19	24	9	48
Scenario 1	Berlin	27	39	13	49
Scenario 1	Munich	26	33	16	49
Scenario 1	Cologne	27	33	16	49
Scenario 1	Hamburg	27	33	16	49
Scenario 1	Düsseldorf	29	33	16	49
Scenario 1	Older Users	29	33	16	49
Scenario 1	Younger Users	32	33	16	55
Scenario 1	Heavy Users	32	33	16	49
Scenario 1	Light Users	27	33	16	49

Table 4.8: Price Sensitivity Meter Analysis Result Summary (Prices in Euro Cent)

Local Adaptation of the Base Price

For adapting a chosen base price locally, analysis in subsection 3.2.4 shows that prices should be standardized on a national or currency zone level in order to ensure transparency, comparability, and the innovative product feature of paying car-based mobility per minute. In fact, providers follow this and standardize prices. Analysis above also shows that price perception does not vary much between cities and DriveNow, offering free-floating carsharing only in Germany at the moment, charges the same price in every city. Also car2go follows the theoretical presumptions of standardizing prices within a currency zone since all offers in Eurozone countries (here: Germany, Netherlands, Austria) are priced at 0.29 EUR/min, the price in both UK cities is 0.35 GBP/min, and in the United States and Canada 0.38 US respectively Canadian Dollars are charged. An overview is given in table 4.9. This example of car2go, at the moment the only international free-floating provider, supports the approach of standardization within currency zones. In addition, also the fleet mix between electric and conventional vehicles (see subsection 4.3.4) should not have an effect of local price adaptation because subsection 3.4.3 revealed that customers are not willing to pay a price premium for electric vehicles as long as there is no added value that comes along, e.g. more space, more power, etc.

From this it follows however, that providers can adjust their price when offering different car models, such as SUVs or sports cars, or when offering other added benefits like airport parking. However, this is not subject to local adaptation but rather a general topic providers have to deal with unless the local vehicle mix, which is considered qualitatively in the framework, is locally adapted. The example of DriveNow, charging a price premium for SUVs and convertibles as well as for airport parking, shows that this is already addressed in practice.

Logically, and supported by theory, the price must be locally adapted when there is a new currency involved. Applying only the exchange rate from an existing to a new market to derive the price in a new currency might be misleading as not only the currency but also price levels and incomes in new markets can be very different. Accordingly, cost structures vary as well, having an effect on the providers' operational costs. These operational costs are not scope of this dissertation and change from provider to provider. It can be assumed however, that a generally higher price level in a country will not only offer the chance to raise prices for the offer but also leads to higher operational costs and vice versa, leaving profit margins unaffected. According to the definition of success in subsection 3.3.1, this work proposes to apply a market-based pricing strategy rather than a cost based pricing strategy to promote the adoption of the concept.

Adapting the price locally should not only rely on the general price level or the general purchasing power parity. These measures are derived from baskets of goods which price levels are compared between countries, including a wide variety of products and services. For free-floating carsharing, the goods in these market baskets are not representative and a generally higher price and income level might not automatically lead to the acceptance of higher prices for mobility. General baskets of goods are valuable for economical inter-country comparisons in real terms of gross domestic product. Therefore, it is more sensible to derive a custom price index for free-floating carsharing which is based on substitution goods from the transportation sector. It can be assumed, that if people are willing to pay a certain price for a substitution, they are also willing to accept the same relative price level for carsharing regardless of the general price level and their income. The need for mobility is seen as constant because it is assumed that the use of carsharing does not induce additional mobility but rather changes the choice of transport mode.

As described by Millard-Ball et al., in its functionality, the carsharing concept is intended to fill the mobility gap between public transport, taxis, bicycles, car rental and private cars. [151] Customers use carsharing to avoid elevated fixed costs of ownership and instead pay higher variable costs in form of fees charged by minute or kilometer. Therefore, carsharing only works in areas with robust transportation alternatives as combined mobility is seen as one of the concepts' strengths. [66] In subsection 3.4.3

it was also found that the costs of alternatives is considered to be a success factor for the concept. From its use case, free-floating carsharing is closest to private cars and taxis. Rental cars are more similar to traditional station-based carsharing and bicycles and public transportation are more complementing ways of transport and therefore prerequisites for the concept rather than being substitutes. This does not mean that single carsharing drives do not substitute public transport but most likely this is not due to the price of public transport but rather due to comfort or time advantage reasons. Many carsharing users even own monthly tickets and a single ride would cost nothing, nevertheless they use carsharing due to different reasoning. For certain use cases, e.g. airport transfers, this might be different and price of public transportation plays a role, but overall it can be concluded that a price index for free-floating carsharing should be based on the price for private car ownership as well as on local taxi costs since their use case is most similar to carsharing (i.e. a car is involved).

In case there is already a free-floating offer in the respective market/city, the competitors price must be evaluated and alignment might be necessary according to the result of the evaluation. This evaluation should question whether the competitor might be too cheap or expensive, how customers accept the price currently, and how a company wants to position itself relative to their competition. Some companies might choose to provide low-cost offers that merely focus on flexible transportation from A-to-B (e.g. car2go) whereas others possibly aim to position themselves higher, offering an additional premium experience (e.g. DriveNow) and therefore charge a price premium.

As a consequence, next to the qualitative alignment to local competitors, for modeling the local adaptation of price levels, local costs of substitution goods must be considered and adapted to. To be able to do so, a basis for adaptation is needed. As discussed, the German market price of in average 0.30 EUR/minute could be useful. The prices of 0.29 EUR of car2go and 0.31 EUR of DriveNow show some sort of positioning and choosing the middle of 0.30 EUR is therefore a good basis for providers to position themselves above or below. Alternatively, a different base price can be chosen according to the determination of the willingness to pay above. Correspondingly, the base price is defined as follows (see discussion above):

$$Price_{Base} = 0.30\ EUR \vee Price\ Point\ in\ Range\ of\ Acceptable\ Prices$$

In other words, one of these price points or the market price of 0.30 EUR are accepted in Germany under the impression of certain substitution costs of taxi and private car use. In a next step, a base index is built which represents the taxi and car ownership costs in Germany accordingly and it is defined as:

$$Index_{Base} = 2 * (\frac{TaxiPrice_{Berlin} + TaxiPrice_{Munich}}{2}) + (\frac{CarPrice_{Berlin} + CarPrice_{Munich}}{2})$$

In the base index, Munich and Berlin are considered since both are big German cities with car2go and DriveNow presence. Also, taxi price is weighted double compared to car ownership costs because free-floating carsharing intends to replace car ownership (see section 2.3) and once diffused, taxis are more likely to be a substitute for free-floating carsharing. Additionally, free-floating carsharing is very similar to the flexibility of taxi services with the distinction that one has to drive on his/her own. The car ownership price cannot be neglected however, since it is also a representation of local policies which should not be undermined. For example, if car ownership is heavily taxed in a market in order to reduce it, offering "cheap" carsharing could lead to disagreement from local authorities which should be avoided, especially when considering how important local regulations (e.g. parking) for the concept are.

Having set the base price and the base index, it is possible to allow for local adaptation of the price, when local taxi and car ownership costs are known. With these two variables, a new index is created, the local index:

$$Index_{Local} = 2 * TaxiPrice_{Local} + CarPrice_{Local}$$

The last determinant for the model is the exchange rate. Considering the exchange rate is important in order to transfer the value of one currency to another. As a result, figure 4.30 sums up the approach chosen and the following model to locally adapt prices is proposed:

$$Price_{Local} = \frac{Index_{Local} * ExchangeRate\ (to\ EUR)}{Index_{Base}} * Price_{Base} * ExchangeRate(from\ EUR)$$

In order to allow for transferability, a common data source should be used when applying the model. The Swiss bank UBS regularly publishes a report on global prices and incomes on a city level called "Preise und Löhne". In its last edition from 2012, 72 cities in 58 countries were considered, [241] making it a valuable data source. To derive the base index as well as the local index, data from this report is used for local taxi prices. For car ownership costs it is not sufficient to simply look at local vehicle prices or taxes such as in the UBS report. Also insurances, gas prices, depreciation, or maintenance have to be considered. Automobile clubs such as the AAA in the US or the ADAC in Germany publish such figures on a regular basis for a variety of vehicles and a variety of annual mileages. Here, typical carsharing vehicles such as a MINI Cooper with an annual mileage of around 15,000 kilometers is chosen to derive the costs of private car ownership on a kilometer / mile basis. These costs can be assessed on a national rather than on a city level because the only difference for car owners in different cities is parking costs, which however depend on the individual person and place of residence.

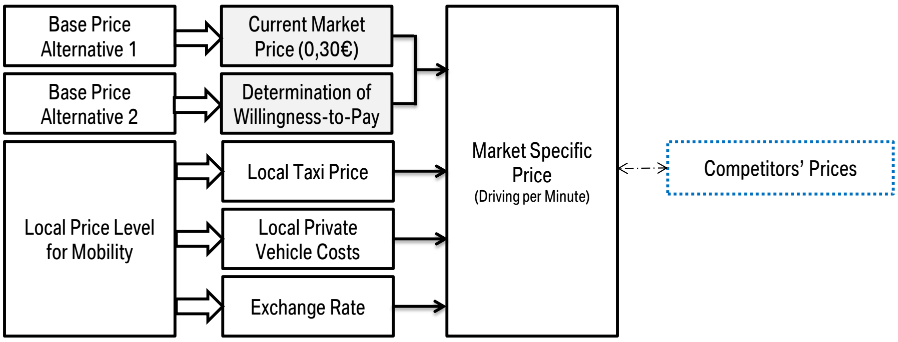


Figure 4.30: Summary of the Price Model Approach

In general, the model should be applied to a city level; however, since standardization is pursued within a currency zone or a country, a lead market has to be defined for price modeling. Usually, this would be the capital or the biggest/most important city of a country respectively the first city that is approached in a new country. All other cities in that country that follow should be priced according to such a lead market.

Evaluation

To apply and evaluate the model, cities in which car2go is currently present are chosen since it is the only international free-floating provider. Car2go is present in cities in the Eurozone, USA, UK, and Canada. Eurozone cities are based according to the German base price and are therefore not modeled, whilst for the US Miami is the lead market (since it is the biggest city where car2go is present), for the United Kingdom it is London, and for Canada it is Toronto.

In a first step, $Index_{Base}$ must be determined. To do so, data for taxi prices [241] (based on a 5 km/3 mile journey) and for a comparable private car ride was used. [2] This results in the following:

$$Index_{Base} = 2 * \frac{8.33\ EUR + 13.93\ EUR}{2} + \frac{0.39\ \frac{EUR}{km} * 5\ km + 0.39\ \frac{EUR}{km} * 5\ km}{2} = 24.23\ EUR$$

Now, the indices for Miami, [241, 5] London, [241, 236] and Toronto [241, 41] are calculated:

$$Index_{Miami} = 2 * 15.32\ USD + \frac{0.45\ USD}{mile} * 3\ miles = 31.99\ USD$$

$$Index_{London} = 2 * 14.33\ GBP + \frac{0.43\ GBP}{mile} * 3\ miles = 29.95\ GBP$$

$$Index_{Toronto} = 2 * 13.33\ CAD + \frac{0.53\ CAD}{mile} * 5\ kilometers = 29.31\ CAD$$

To apply the model, only exchange rates are missing which were set at: 1 EUR in USD = 1.3091, in GBP = 0.8651, in CAD = 1.3647 (Effective July 16th, 2013)

The model can be applied accordingly (using the market price of 0.30 EUR as base price):

$$Price_{Miami} = (\frac{31.99\ USD * \frac{1}{1.3091}}{24.23\ EUR}) * 0.30\ EUR * 1.3091 = 0.39\ USD$$

$$Price_{London} = (\frac{29.95\ GBP * \frac{1}{0.8651}}{24.23\ EUR}) * 0.30\ EUR * 0.8651 = 0.37\ GBP$$

$$Price_{Toronto} = (\frac{29.31\ CAD * \frac{1}{1.3647}}{24.23\ EUR}) * 0.30\ EUR * 1.3647 = 0.37\ CAD$$

In order to evaluate the output of the model, prices are compared with real prices from car2go (see table 4.9). As mentioned before, the base price was built as average price from car2go and DriveNow according to their positioning and as a consequence, the modeled prices should be slightly above the real car2go prices. Furthermore, the explained lead market approach is applied which means that e.g. the determined price for Miami is set as standard for all US cities.

The result is that the modeled price for the US and Canada deviate by only 0.01 USD. For the US, this is the expected deviation due to the positioning of car2go. Prices for Canada might be standardized according to US prices, since both countries are strongly intertwined and prices might be standardized across borders and currencies. This would ease communication and customer understanding since there might be many customers using the system in both countries. The price for London was determined to be 0.37 GBP in comparison to 0.35 GBP. When adjusting the price again downwards due to positioning, there is only one pence difference to the actual price of car2go. This difference might be accounted for by other reasons, such as the competitive environment in London where Zipcar has a very strong local base for station-based carsharing.

All in all, the proposed model appears to return valid results when using the German market price as base price and compared with the approach of car2go. Pricing is always a sensible issue that is driven by a variety of company specific factors and the market environment an offer is placed in. Nevertheless, the proposed model can surely give guidance when adopting the prices for free-floating carsharing systems to local markets.

City	**Country/ Monetary Union**	**Driving Price (per minute)**	**Modeled Price**
Amsterdam	Eurozone	0,29 EUR	- (base price)
Austin	USA	0,38 USD	0.39 USD
Berlin	Eurozone	0,29 EUR	-
Birmingham	UK	0,35 GBP	0.37 GBP
Calgary	Canada	0,38 CAD	0.37 CAD
Denver	USA	0,38 USD	0.39 USD
Düsseldorf	Eurozone	0,29 EUR	-
Hamburg	Eurozone	0,29 EUR	-
Cologne	Eurozone	0,29 EUR	-
London	UK	0,35 GBP	0.37 GBP
Miami	USA	0,38 USD	0.39 USD
Munich	Eurozone	0,29 EUR	-
Portland	USA	0,38 USD	0.39 USD
San Diego	USA	0,38 USD	0.39 USD
Seattle	USA	0,38 USD	0.39 USD
Stuttgart	Eurozone	0,29 EUR	-
Toronto	Canada	0,38 CAD	0.37 CAD
Ulm	Eurozone	0,29 EUR	-
Vancouver	Canada	0,38 CAD	0.37 CAD
Washington	USA	0,38 USD	0.39 USD
Vienna	Eurozone	0,29 EUR	-

Table 4.9: Evaluation: Actual vs. Modeled Prices of car2go [42]

4.4 Derivation of the Model-Based Framework

In the previous section five individual models were developed and each of these models has a certain set of input and output parameters as well as the models are interrelated.

The first model outputs the operating area and relies on population density, city center distance, housing rent, and hotel-/restaurant density as input parameters. In addition to those quantitative inputs, experts must also carry out a qualitative alignment with a city map to exclude water, large parks, etc., on-street parking possibilities, and the technology and spatial distribution of existing charging infrastructure to be able to define the operating area.

The size of the operating area as well as target utilization and the desired spatial coverage of the system are the three inputs for the second model which helps in the deviation of the fleet size.

The third model which determines the charging concept also relies on the input of the operating area as well as the number of charging stations in the operating area is considered. Additionally, the spatial distribution and technology of chargers must be considered qualitatively and potentially, the charging concept must be aligned – e.g. when all chargers are only in a small area or their technology is unsuitable. The so defined charging concept will influence the target utilization which is needed in the determination of the fleet size and this circular reference must be solved by setting the target utilization respectively.

Along with the number of chargers in the operating area and a potential strategic or regulatory minimum percentage of electric vehicles which might have to be employed, the charging concept determines the fleet mix regarding the drivetrain. This mix of electric and conventional vehicles should then be reviewed qualitatively whether the respective car models fit in with the local vehicle mix and potentially the fleet mix must be aligned to suit local conditions.

The fifth and final model helps to determine the minutely price for a free-floating carsharing system in a city. Quantitative input factors are a base price for adaptation, local taxi costs, local private car costs, and the exchange rate. The modeled price must then be aligned with the chosen fleet mix because for more useful/valuable cars there could be a price premium as well as competitor prices must be considered in order to position the offer correctly.

The combination of all five models in their entirety with all in- and outputs and interrelationships represent the model-based framework. Figure 4.31 illustrates this.

With this framework, decision makers are supported when adopting free-floating carsharing systems to local markets. It incorporates critical and important input factors that need to be acquired for planned analyses. The functional unit then enables decision makers to cope with reality with its full complexity and tries to make use of quantitative data where useful and possible. Where necessary, this is complemented with alignment with "soft factors". Through this mechanism, the five most critical and complex aspects of free-floating carsharing that have to be adapted locally can be determined.

In the application of the framework it is important to be aware of potential circular

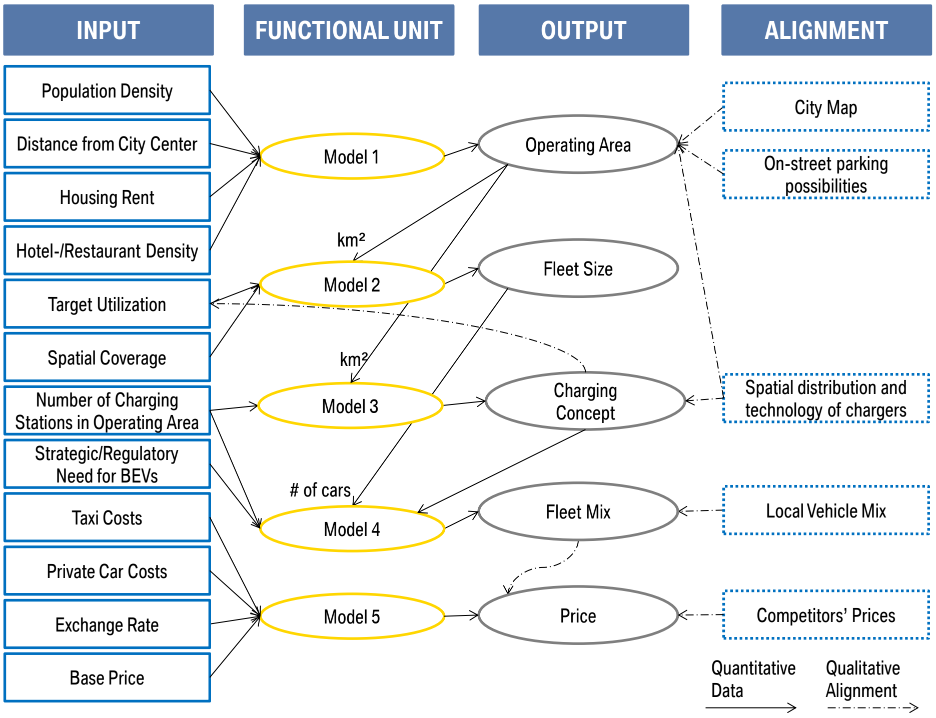


Figure 4.31: Illustration of the Model-Based Framework

relationships. Therefore, it is recommended to apply the framework in the given order of models since the operating area is the cornerstone for all other models and success. As discussed, defining the operating area means defining the target market and to a wide extent also the target customers. It is not advisable for example, to set the fleet size first and then look for an operating area that ”fits” the planned amount of cars. Through such a course of action market potential might be missed or unattractive areas could be included. Other circular relationships can be coped with by the model-based framework. For example setting the price very low will lead to more bookings and more cars than initially planned are needed. This however is considered in the model since fleet size constantly adapts to growing utilization rates.

4.5 Software Implementation: A Prototype Decision Support System

To bring the model-based framework into application, a prototype computer-aided implementation as a Decision Support System is developed. Decision Support Systems

(DSS) are ”computer technology solutions that can be used to support complex decision making and problem solving”. [216] In concrete terms, the model-based framework (as depicted in figure 4.31) is implemented in Microsoft Excel, [150] complemented by the add-in ExcelToDBF to allow for the manipulation of geographical information [31] as well as Google Earth [104] for the depiction of information on a map. With this solution the requirements of ”operability” and ”adjustment” can be fulfilled because Excel is the industry standard for spreadsheets and ExcelToDBF and Google Earth are freeware and easy to use. This avoids extensive costs, training and computing efforts. Accordingly, operators of the software can easily implement adjustments over time and for their specific needs. Figure 4.32 gives an overview on the operating principle of the Decision Support System.

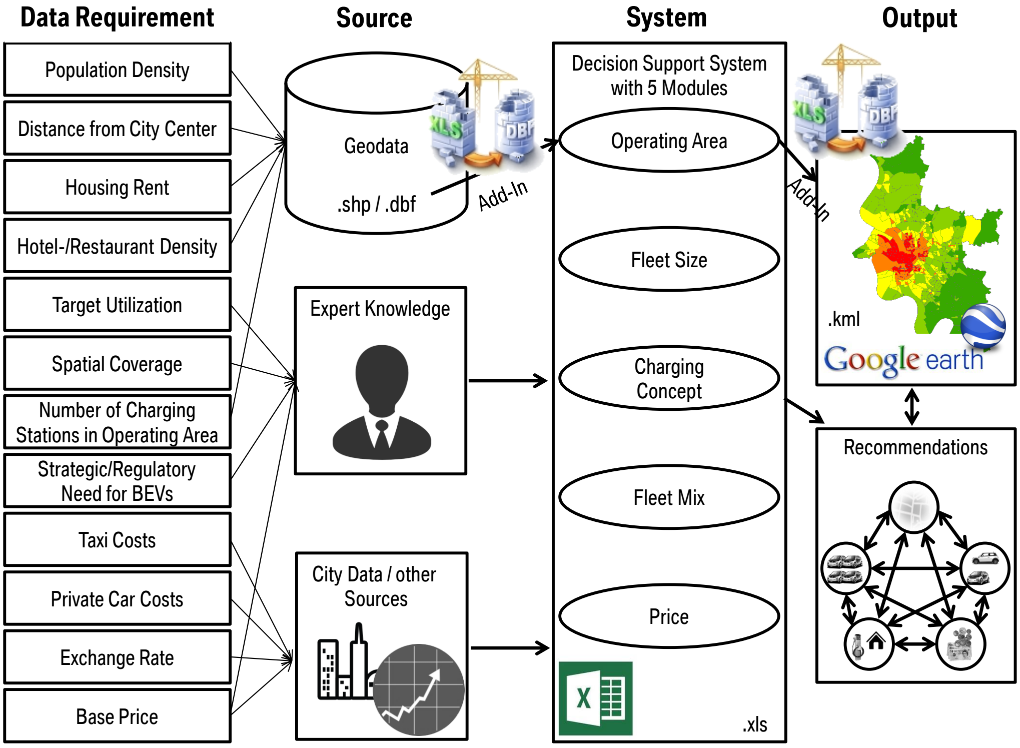


Figure 4.32: Overview on the Operating Principle of the Decision Support System

The program is divided in five modules whereas each module is an Excel spreadsheet, each representing one model (operating area, fleet size, charging mode, fleet mix, and price). Each sheet has a step-by-step guidance on how to use the tool, input data, and interpret results. The functional unit or ”calculation areas” are hidden for the user to allow for easy handling, as well as a variety of VBA (Visual Basic for Applications) coded macros assists the user. Further, results and assisting graphics are illustrated through a variety of plots.

Specifically for the determination of the operating area, the tool helps to manipulate geographical data and guides on the import of data into Google Earth, where detailed analyses and the detailed planning of the operating area is carried out. To do so, the acquired geographic variables population density, rent, city center distance, and hotel-/and restaurant density have to be pasted in the tool along with a tract ID and the area of the respective segment. These two optional and additional inputs ensure the quality of the input and allow for validity checks, but are not essential to the output. After having pasted the information in the tool the user merely has to push ”calculate” and in the background, indexes of the variables are created and the regression model is applied. The outcome, the forecast ”relative booking density” is now presented to the user as well as quintiles are calculated for coloring the map in five categories. Consequently, a step-by-step guidance explains the user thoroughly how to create a map from this data in Google Earth with the help of the ExcelToDBF add-in. An impression shall be given in figure 4.33, depicting a screenshot of Google Earth where an operating for London is assessed (data is provided by GeoLytix [99]). In Google Earth the user is able to overlay the forecast model with other geographic information that might be needed (controlled parking zones, not accessible areas, waterland, parks, etc.) to determine the operating area. The area of this zone must then be entered into the tool and for information, the chosen size of the operating area is compared to those of other cities, normalized by the total population of a city and, in another plot, by the cities' overall population densities. Figure G.1 in Appendix G shows a screenshot of the operating area module.

To move to the next part of the tool, figure G.2 in Appendix G shows a screenshot of the fleet size part with step-by-step guidance on the left, input parameters in green, the resulting fleet size in red, performance indicators in grey, as well as with plots for validation and performance review. In concrete terms, users must choose the aimed target utilization and spatial coverage they want to achieve with the carsharing system. To validate these inputs, users must click ”update plots” and three information plots are given. The first shows the expected utilization during a typical weekday and a typical weekend in order to review whether the chosen utilization accounts for enough ”buffer” in peak times. The second plot shows the relationship of spatial coverage and fleet size at the chosen utilization. Here, users can see how other input values for spatial coverage affect the fleet size and that potentially a higher choice might end up in a disproportionately growing fleet size. Eventually, graph three gives information of

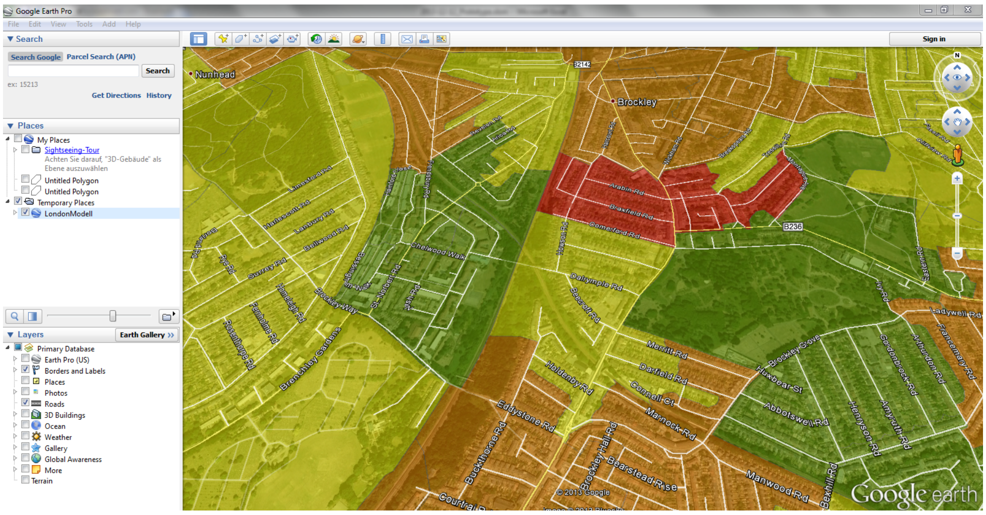


Figure 4.33: Screenshot of the Google Earth-Implementation of the Model-Based Framework

the expected fleet size when the member base is growing and shows potential savings when starting with a smaller fleet. This graph is based on the simple assumption that customers behave similar and thus constant average values are estimated. The purpose of this graph is simply to illustrate the fact that the fleet size is growing constantly and must be adapted to a growing customer base to keep utilization constant at the target rate. Once confident inputs for utilization and spatial coverage were determined, the tool shows a resulting fleet size. This number is a snapshot of the future since it is the ideal fleet size at the point where there are enough customers to utilize the fleet at the chosen rate. For further validation, performance indicators are given showing the overall vehicle density (vehicles per km^2) and the peak-time vehicle density. Also, the minimum launch fleet (at an initial utilization of 0%) is shown for information purposes.

The third part of the prototype decision-support-system is the charging concept module. Here, the user must enter the number of charging stations within the operating area and is advised, to visually check the spatial distribution and technology of the chargers. The tool returns a recommendation for the charging concept but since the latter check is carried out qualitatively, the user has the possibility to overwrite the charging concept. Also, as described in detail in subsection 4.3.3, the recommendation is based on a threshold value, therefore it underlies a certain sensitivity and the given plot shows whether there are tendencies towards centralized or decentralized charging concepts. Potentially, future developments (e.g. plans to build more charging stations) might open up new possibilities. Further, to assess and actively push investment into infrastructure, the number of stations per square kilometer is indicated as well as how many stations are missing to employ decentralized charging. Figure G.3 in Appendix G shows a screenshot of this module.

The fourth module concerns the fleet mix. Here, all inputs stem from other modules except the potential strategic or regulatory need for a fixed share of electric vehicles in the fleet. Such an input would overwrite the recommendation of the tool, which is displayed as percentage, absolute number of cars, and as tangible illustration the average walking distance to the next electric vehicle in minutes. Additionally, a pie chart is given for visualization as figure G.4 in Appendix G shows.

Fifth and finally, the price module – depicted in figure G.5 in Appendix G – must be explained. The structure of this module is very simple since users must only enter a base price, local taxi costs, local private car costs, and the exchange rate to Euro of the considered market. Here, the tool also guides on which sources to use and how the data should be tracked down. The software then calculates a price recommendation and advises users to compare this to actual prices of competitors to position their offers accordingly. Moreover, the price module shows a comparison with other prices charged currently by DriveNow and car2go in the respective markets.

There are a variety of use cases for this tool; specifically however, the roll-out planning for new cities where a free-floating carsharing system shall be launched as well as the evaluation of the configuration of existing markets should be the most common. It is also possible to use only parts of the tool, e.g. to verify pricing.

Since this decision-support-system still needs a variety of manual operations and relies on third party software packages, it is considered as a prototype for practical implementation rather than a fully-fledged decision-support-system.

As a side remark, also the agent-based simulation which is explained in detail in subsection 4.3.2 should be mentioned in this context. Whilst a strong database with ca. 20,000 different combinations of utilization and vehicle densities was created and incorporated in the Excel-based tool as simulation result database, this does not account for every possible combination. For this case, the NetLogo-based simulation can be used separately to determine the spatial coverage of a certain combination of fleet size and utilization.

4.6 Model Validation: Application to Chicago

The aim of this section is to demonstrate and evaluate the applicability of the model-based framework. Therefore, a free-floating carsharing system is planned out for Chicago, IL, USA, which was chosen as it is a big North American city that does not yet have a free-floating carsharing system. Since the models, the framework and its software implementation were already explained, the application of the latter is the next logical step.

The first aspect that is determined for Chicago is the operating area. To do so, four variables - population density, hotel-/restaurant density, city center distance, and housing rent - were acquired from Spatial Insights [219] on census tract level. Here, the greater metropolitan area of Chicago with its 9.1 million inhabitants was chosen for analysis. In other contexts a different definition of a "city" might be chosen. For example, this could be sensible if the city border goes in hand with different municipalities and hence different political attitudes and parking regulations.

To carry out analysis and create a forecast model, the acquired data must be copied in the tool, calculations are processed and guidance is given on how to import the layer to Google Earth. The result of this steps is given in figure 4.34.

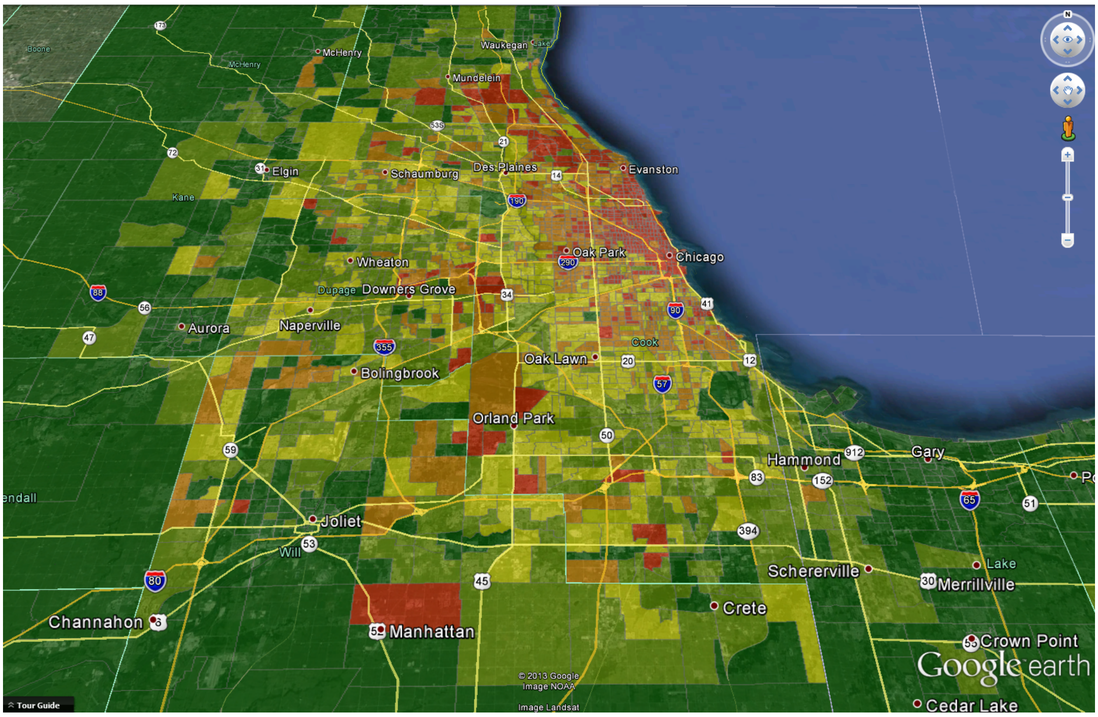


Figure 4.34: Screenshot of the Operating Area Forecast Model in Google Earth for Chicago

According to the framework, the operating area should be designed with the help of the forecast model and the qualitative consideration of a city map and on-street parking possibilities. Parking regulations however can only be determined by contacting the respective city on whether they support a free-floating carsharing system in their city and issue parking permits. This step is skipped since this is only an exemplary planning process. Apart from that, considering the city map is very helpful. Whilst the forecast model suggests every red, orange, or yellow colored area as potentially interesting, a look at the map revealed that some of these areas are parks or very sprawled neighborhoods where detached houses are prevalent. Figure 4.35 shows an exemplary screenshot of such a case. In these areas - mostly far from the city center – it is unlikely that a free-floating system would be successful even though the model might suggest it.

Figure 4.35: Screenshot of a Potential Forecast Error in the Operating Area Forecast Model in Google Earth for Chicago

Furthermore, the operating area should be easy to remember and communicate. Even though it is possible to show the operating area in the vehicle and the booking platform, customers should be able to roughly know which trips can be taken and which trips are out of reach. Therefore, it should be aimed to make the operating area coherent (whilst potentially connecting some highly attractive ”islands”) as well as natural borders like rivers or main streets should be incorporated in the border.

Considering this, an exemplary operating area was determined for Chicago and this is depicted in figure 4.39. This area comprises 259km^2 and mainly orientates on the lake shore in the east, Touhy Avenue in the north, Harlem Avenue in the west, and Stevenson Expressway as well as Dwight D Eisenhower Expressway in the south. Further, a small area known as Indian Village and Hyde Park was chosen as attractive ”island” in the south of the main operating area. Lastly, in order to potentially enable the use of electric vehicles, the locations of charging stations were considered.

The next aspect that has to be determined is the fleet size. Here, a target utilization of 15% is chosen to ensure availability also in peak times whilst utilizing he vehicles economically as well. Further, the spatial coverage is set to 40% because experience with such a coverage shows a good reception by customers. Accordingly, 1044 vehicles should be employed in Chicago. As figure 4.36 shows, this means that also in peak times 700 vehicles (=2.7 per km^2) are available. Since this is a rather conservative approach, no smaller starting fleet is considered, even though the software suggests that 887 vehicles would be sufficient in the beginning because there are no customers yet who utilize the vehicles.

If a more bold approach should be chosen along with the assumption that a better availability leads to a more successful system, more vehicles should be employed. Figure 4.37 shows which spatial coverage can be reached with which fleet size, e.g. to reach 60% coverage, 2117 vehicles would be necessary.

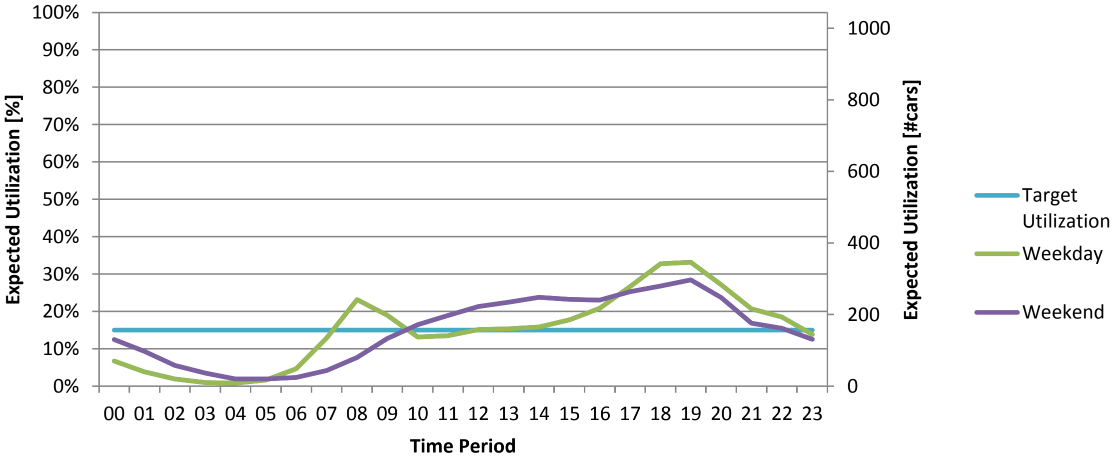


Figure 4.36: Expected Utilization of the Fleet (1044 Cars) in Chicago

The third aspect to be determined concerns the charging concept. As analysis in Google Earth revealed, there are only 59 charging stations within the operating area, even though the determination of this area considered the location of chargers. This results in only 0.23 charging stations per km^2 and is thus far below the threshold value of three for decentralized charging concepts. Moreover, the stations are highly clustered and big proportions of the operating area are not covered and thus unattractive

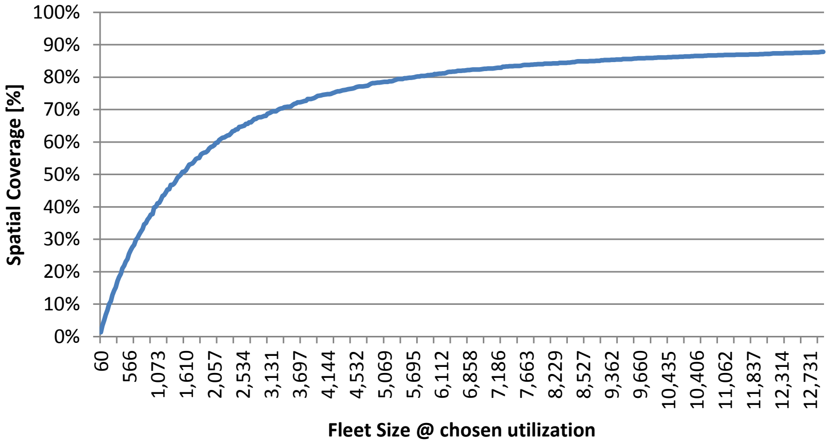


Figure 4.37: Expected Spatial Coverage of the Fleet (1044 Cars) in Chicago at 15% Utilization

for electric vehicles. To reach the threshold charging station density for decentralized charging, at least 718 additional chargers must be built and ideally, they should be distributed evenly in the operating area and hotspots should be equipped with DC fast-chargers. Due to these circumstances, it is advised to charge electric vehicles centrally - if these are needed or strategically desired. Because of the huge gap to reach a decentralized concept, no manual overwriting of this recommendation is carried out and the charging concept is set to be centralized.

This fact strongly influences the next aspect, the fleet mix. Since a centralized charging concept is disadvantageous to customers and providers, it is recommended not to employ electric vehicles and accordingly the fleet consists of 100% conventional vehicles. In case e.g. the city wishes at least 20% electric vehicles in order to issue parking permits for the operator, this can be entered manually in the tool but in the case of Chicago such a requirement is not known. Another consideration is to look at the type of vehicle(s) that should be employed in Chicago and how this blends in with the local vehicle landscape of rather big (from an European point of view) cars and how the chosen vehicles might fit the local needs e.g. for seat or luggage capacity.

Fifth and finally, the price for a free-floating carsharing system in Chicago is determined. In this application, the actual market price of similar systems in Germany of 0.30 EUR is set as a base price for local adaptation. This local adaptation relies on the local taxi price and private car costs. According to UBS [241], the reference price for taxis is $13.25 and according to the AAA, private car costs amount to $0.45 per mile for a typical carsharing vehicle. [5] The last input is the exchange rate which is set at 1.3731 US Dollar per Euro. Given these inputs, a local price of $0.34 is suggested, translating to 0.25 EUR per minute. Given the lower costs for alternatives in Chicago and the exchange rate, this price seems low compared to other prices in reality as indicated by figure 4.38. However, the approach of car2go in the US seems to be similar as subsection 4.3.5 showed. Here it was assumed that Miami was the lead market for car2go in the US and therefore evaluation results were correct. If a provider chooses another city in the United States as lead market, results will vary accordingly. Moreover, this price is only a guideline and positioning results in lower or higher prices, e.g. if a premium service with high-end vehicles is offered. Lastly, the suggested price must be aligned with prices of competitors in Chicago. As for now, Chicago has no free-floating carsharing system but if there was one, its price must be analyzed and the offer should be positioned according to ones' strategy.

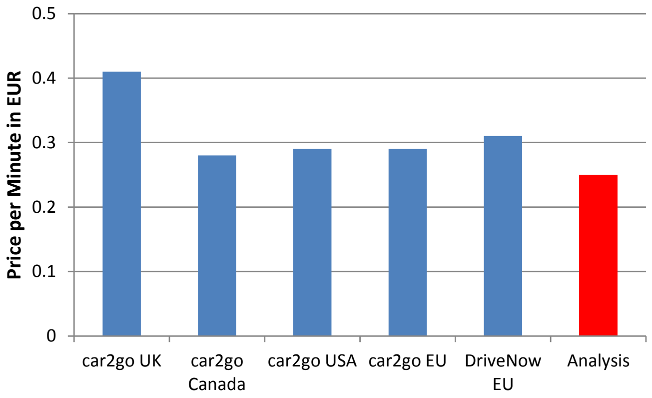
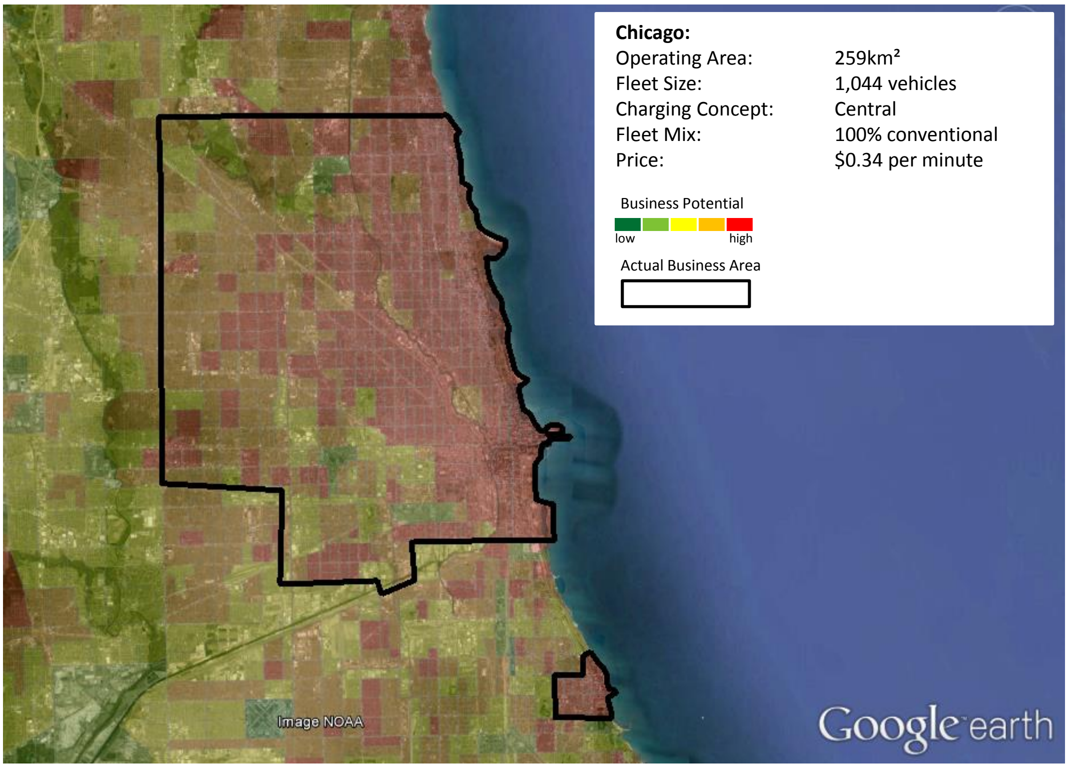


Figure 4.38: Modeled Price for Chicago in Comparison to Other Markets and Offers

In conclusion, figure 4.39 summarizes the planned out free-floating carsharing system for Chicago.



Chicago:

Operating Area:	259km²
Fleet Size:	1,044 vehicles
Charging Concept:	Central
Fleet Mix:	100% conventional
Price:	$0.34 per minute

Figure 4.39: Screenshot of a Potential Operating Area for Chicago and Key Analysis Results

Chapter 5

Conclusion and Future Research

5.1 Summary and Conclusions

This dissertation developed a model-based framework which supports decision makers to design free-floating carsharing systems that are adapted to local markets and accordingly, it answers the research question of ”how shall free-floating carsharing systems be adapted to local markets”. This research question cannot be answered with a single sentence or a single solution because every city is different. The model-based framework and its implementation as Decision Support System help enquirers to answer the question individually for each city and furthermore, this dissertation provides a great pool of information and knowledge to contrive a solution for the local design of free-floating carsharing systems.

The model-based framework comprises the design of the operating area, fleet size, charging concept, fleet mix, and price because these five aspects were identified as key elements when adapting free-floating carsharing to a city. Of course, there are also various other elements that cannot be standardized across markets such as communication or local partners but these adaptive aspects do not need modeling and are rather simple to-dos. Even though a total standardization would lead to cost savings and speed up roll-out, free-floating carsharing systems must always fulfill local needs and integrate in the local transportation system and must therefore be adapted accordingly.

Luckily, this work could rely on real GPS booking and customer data which is very rare for this cutting edge transportation system since there are only few providers which are very restrictive with their data. Analyzing this data with the help of descriptive statistics alone can be seen as contribution to the body of knowledge because the behavior of free-floating carsharing systems is mostly unknown to transportation researchers. This analysis also lead to a key result of this thesis, the answer which performance indicator is suitable to measure the success of a free-floating carsharing system. As a result, booking density as geographically assignable measure appeared as best measure.

In order to incorporate a city's attributes in the design of carsharing systems, a success factor approach was chosen, first qualitatively and then quantitatively measuring the effect of certain characteristics to success (booking density) within a city. Also, this step in analysis is of unique nature since there has been a reasonable amount of research studying traditional station-based carsharing and "where and how it succeeds", but for free-floating carsharing, this work breaks new ground.

Backed up by all these findings, the model-based framework was developed, answering the research question and tackling the challenges free-floating carsharing currently faces such as limited profitability, limited diffusion of the concept, and limited market knowledge. In summary, twelve quantitative input variables and five qualitative aspects to be considered qualitatively are modeled as adjusting screws to determine the five key aspects of this transportation system.

The development of a prototype Decision Support System gives decision makers a powerful tool on hand to plan for the key trend of the industry, expansion to new markets internationally and out of its niche to the mass market. The applicability of the tool was demonstrated on the example of Chicago in this thesis and moreover, it was implemented in industry. Being supported in determining some of the key aspects of the system is seen as great help by practitioners as well as it is valued that the framework returns key input parameters for business case computation in city assessment. The framework limits complexity and enables managers to focus on what is important. The individual models of the framework were evaluated wherever possible and results were very satisfactory even though it must be stressed again that it *supports* decision makers and does not *replace* them; hence, results need human verification and qualitative adjustment.

Additionally, again every individual model created entered new territory, even though few researchers dealt with some of the problems such as fleet sizing but never in the context of a holistic local adaptation of a whole new system to a city. This holistic approach is probably the greatest strength of this piece of work since it presents a reference for further research in the many fields that were opened with this dissertation. Moreover though, it provides practitioners with a strong tool set to actually design free-floating carsharing systems and therefore optimize current and future systems. As this dissertation outlined in chapter 2, free-floating carsharing offers many advantages and answers a variety of challenges in transportation. Therefore, developing a tool that is used in real world application and helps this great innovation to diffuse contributes not only to the academic world, but it might also improve some of the issues transportation and therefore society faces, admittedly however on the small scale at disposal of a PhD thesis.

5.2 Limitations and Future Research

The first limitation of this dissertation concerns the analysis on which aspects must be locally adapted. The study gives clear indication on how to handle the debate on standardization versus adaptation for carsharing, but its representativity is limited. The use of multiple sources was constrained due to the strategic importance of this question for companies. Answering the question of ”which aspects must be locally adapted?” means discussing a strategic management decision and many companies do not want to reveal their strategy and their reasoning behind. Accordingly, in this analysis step, certain bias is given because ten of the twelve interviewed experts work for the same corporation. If possible, this part of the research should be repeated in future when there are more market players than today and potentially, at this point companies will also have more experience with the international roll-out, which could improve research as well. Furthermore, a study on adaptation vs standardization in the carsharing context could also have a stronger marketing focus and work out details in local adaptation such as for example adding local product features.

The next limitations and future research potentials concern the GPS booking and customer data used. Analysis and the models developed are only as good as the data that was available. The database was limited to two cities for development and one city for evaluation. Once the innovation diffused to more cities and some time has passed, it is advisable to carry out analysis again and re-calibrate the model-based framework. Ideally, the international dispersion of cities is more significant than nowadays since German cities - even though very different ones – might not be representative internationally. Also, in an ideal world data would stem from a variety of providers of free-floating carsharing. It is questionable however, if different organizations will disclose their GPS booking and customer data to one researcher.

Repeating analysis is also interesting because results from data analysis can only be a snapshot in time - customers will change and thereby also the propositions must change. Available data relies on the adoption of innovators and early adopters in few cities whose characteristics are very different from customer groups in the mass market. This is not a problem as expanding to new cities means that a similar customer base will need to be approached each time. Therefore, the developed models primarily give guidelines for approaching new cities. Once carsharing is offered in a city for a longer period, further development must primarily be guided by customer feedback.

Due to this limitations in data availability, the model-based framework has a certain self-fulfilling prophecy problem. For example, the framework recommends an operating area based on experiences in Berlin and Munich which however were planned out based on expert knowledge rather than scientific evaluation. For this reason it is theoretically possible that other areas that were never considered are interesting and therefore influencing variables that were out of reach in the dataset could lead to a better result. On the other hand, this is very unlikely and this problem could only be solved by carrying out expensive field tests which is an approach that is diametrically opposed to that of the model-based framework.

An issue that often came up in the development of this dissertation is the order in which the model-based framework is applied. The hypothesis this research underlies is that the determination of an attractive area where to offer the system in determines the market and the target customers and therefore, everything else should follow after. For example, determining the fleet size first and then find ”a space” where to put the cars is not a sensible approach in the opinion of the author. Nevertheless, interference in-between models of the framework is not considered as no data is available - e.g. setting a lower price might lead to longer trips and different behavior and therefore the operating area might have to be laid out differently. Also, feedback effects are factored out because offering carsharing in a city will change the city and this in turn will influence carsharing again.

Furthermore, the individual models open up possibilities for refinement and extension:

- **Operating Area**: Research on whether local features such as an airport, a leisure center, or a furniture store could be detected and included in the model should be carried out. Looking at typical origins and destinations of potential users as well as studying alternatives for transportation might reveal gaps in the transportation-network that might be filled with free-floating carsharing. Further refinement to the operating area model could stem from inclusion of data that indicates on-street parking possibilities; both, space and regulation wise. This could replace much of the qualitative alignment that has to be carried out today.

- **Fleet Size**: A major question that came up in the development of the fleet size model is whether a better availability leads to more bookings and if yes, how is the relationship? Theoretically, bookings should increase over-proportionally since a more reliable system gives customers more peace of mind to give up their own car and switch their automobile mobility needs to the carsharing system. However, this can only be proven if different fleet sizes and their effects are tried out in reality over a long observation period.
- **Charging Concept**: This work takes the existing charging infrastructure in cities as given. However, in reality carsharing providers might build their own infrastructure or influence the local setting by bringing in negotiating power since they will – at least at first – be major users of chargers. Therefore, supporting carsharing providers with a tool to determine the optimum number, location, and technology of chargers can be useful. For this, it is necessary not to look at carsahring data only but to include other potential users of the infrastructure and local transportation policies as well since their individual goals must be aligned and optimized holistically.
- **Fleet Mix**: Analysis on effects of different vehicle types on user behavior and how this is connected to the local fleet might reveal interesting results. Here, data on local vehicles as well as focus groups with customers in different settings might be necessary. It must be analyzed whether to blend in or not with the local fleet, also testing the approach of car2go to offer a practical city car for the use in a city regardless of the local circumstances.
- **Price**: The best way to determine an optimal price point for a product is to observe effects on buying behavior once the price is changed or once there is a number of comparable offers at different price points. Accordingly, providers must carry out real world tests with different prices. Only then it is possible to determine reliable price elasticity functions with which providers could set their price point according to their individual strategy and settings.

Apart from that, an interesting field for research is the determination of appropriate framework conditions for free-floating carsharing to diffuse. This dissertation is mainly concerned with company internal optimization of carsharing systems rather than with external reasoning to design framework conditions that make carsharing work. Local adaptation and optimizing the offer is important but without the right framework conditions there will be no offers. For example, without a parking permit free-floating carsharing cannot work. The same is true for other discriminatory rules such as preferred parking for privately-owned resident vehicles. However, these conditions are set by local municipalities but research could help policy makers and carsharing providers to jointly evaluate which conditions to set in order to reach common goals such as traffic reduction.

Another topic that might be of interest for future researchers is the analysis of discrepancies, effects and interrelatedness of free-floating and station-based concepts.

Further, this research studied success factors for the local adaptation on a micro level within a city. As the qualitative determination of success factors showed however, there is a vast amount of potential success factors on a macro level between cities. For example, the overall population density in a city like Tokio could be so high, that driving a car - if shared or not - is simply unattractive and free-floating carsharing might not work well there. Again, the problem lies in data availability. So far, there are not enough cities to carry out an overarching city analysis which could apply a regression analysis, for example. Furthermore, even if there were more cities, it will be a challenge to incorporate distorting facts such as different launch dates and therefore different diffusion stages or different local framework conditions that might skew the picture. Also, product attributes or marketing efforts play a role that can hardly be segregated from other success factors.

As a final remark, the greatest strength of this dissertation is probably also its greatest weakness. For this point in time in the development of free-floating carsharing a holistic approach was considered best. As laid out however, almost every section of this dissertation breaks new ground. Therefore, there is plenty of room for further research to deepen and improve insights on each of the topics raised and models developed. For the near future however, it appears best to implement the model-based framework, observe effects, and learn from the further diffusion of free-floating carsharing to our societies.

List of Tables

List of Figures

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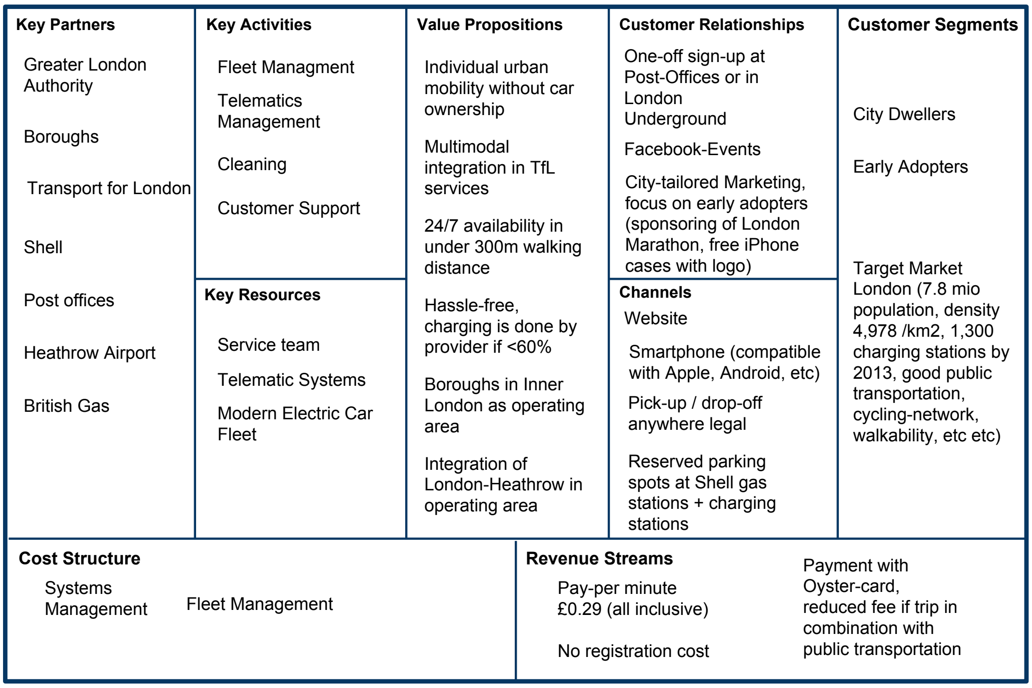
Appendix A

Structuring Carsharing Systems: Illustrations on the Carsharing Business Model, Blueprint, and Service Marketing Mix



Key Partners

Greater London Authority

Boroughs

Transport for London

Shell

Post offices

Heathrow Airport

British Gas

Key Activities

Fleet Managment

Telematics Management

Cleaning

Customer Support

Key Resources

Service team

Telematic Systems

Modern Electric Car Fleet

Value Propositions

Individual urban mobility without car ownership

Multimodal integration in TfL services

24/7 availability in under 300m walking distance

Hassle-free, charging is done by provider if <60%

Boroughs in Inner London as operating area

Integration of London-Heathrow in operating area

Customer Relationships

One-off sign-up at Post-Offices or in London Underground

Facebook-Events

City-tailored Marketing, focus on early adopters (sponsoring of London Marathon, free iPhone cases with logo)

Channels

Website

Smartphone (compatible with Apple, Android, etc)

Pick-up / drop-off anywhere legal

Reserved parking spots at Shell gas stations + charging stations

Customer Segments

City Dwellers

Early Adopters

Target Market London (7.8 mio population, density 4,978 /km2, 1,300 charging stations by 2013, good public transportation, cycling-network, walkability, etc etc)

Cost Structure

Systems Management

Fleet Management

Revenue Streams

Pay-per minute £0.29 (all inclusive)

No registration cost

Payment with Oyster-card, reduced fee if trip in combination with public transportation

Figure A.1: Simplified and Exemplary Business Model Canvas for a Free-Floating Carsharing Systems in London (Adopted from [173])

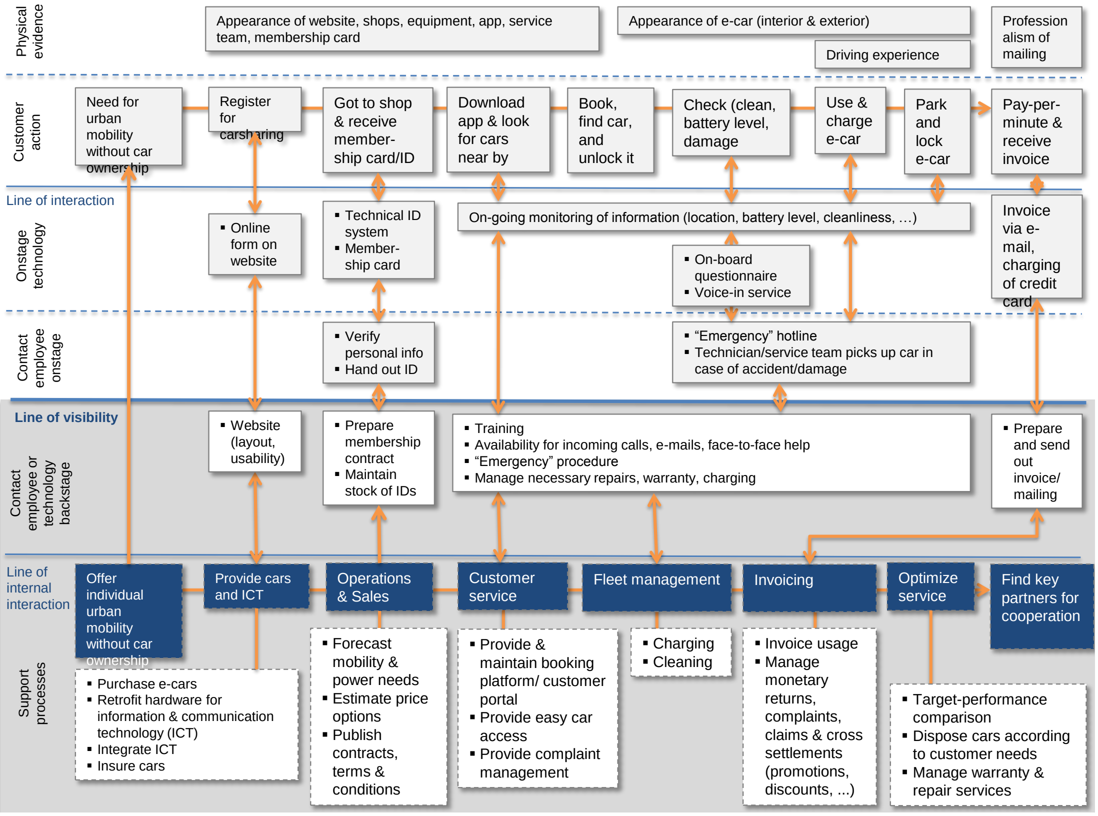


Figure A.2: Exemplary Service Blueprint for Carsharing. Based on Gremler's Six Components. [107]

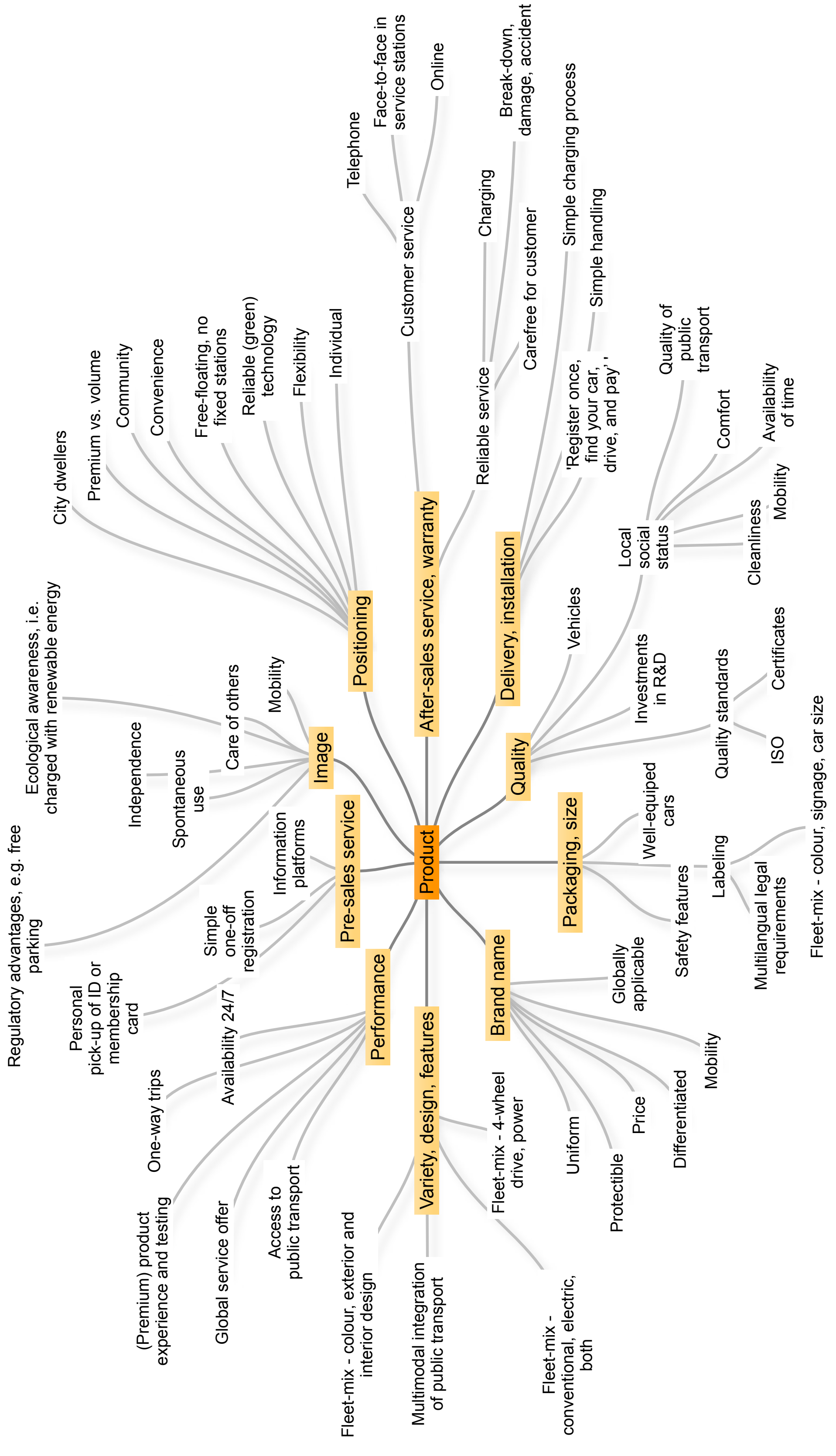


Figure A.3: Marketing Mix Element Product for Carsharing

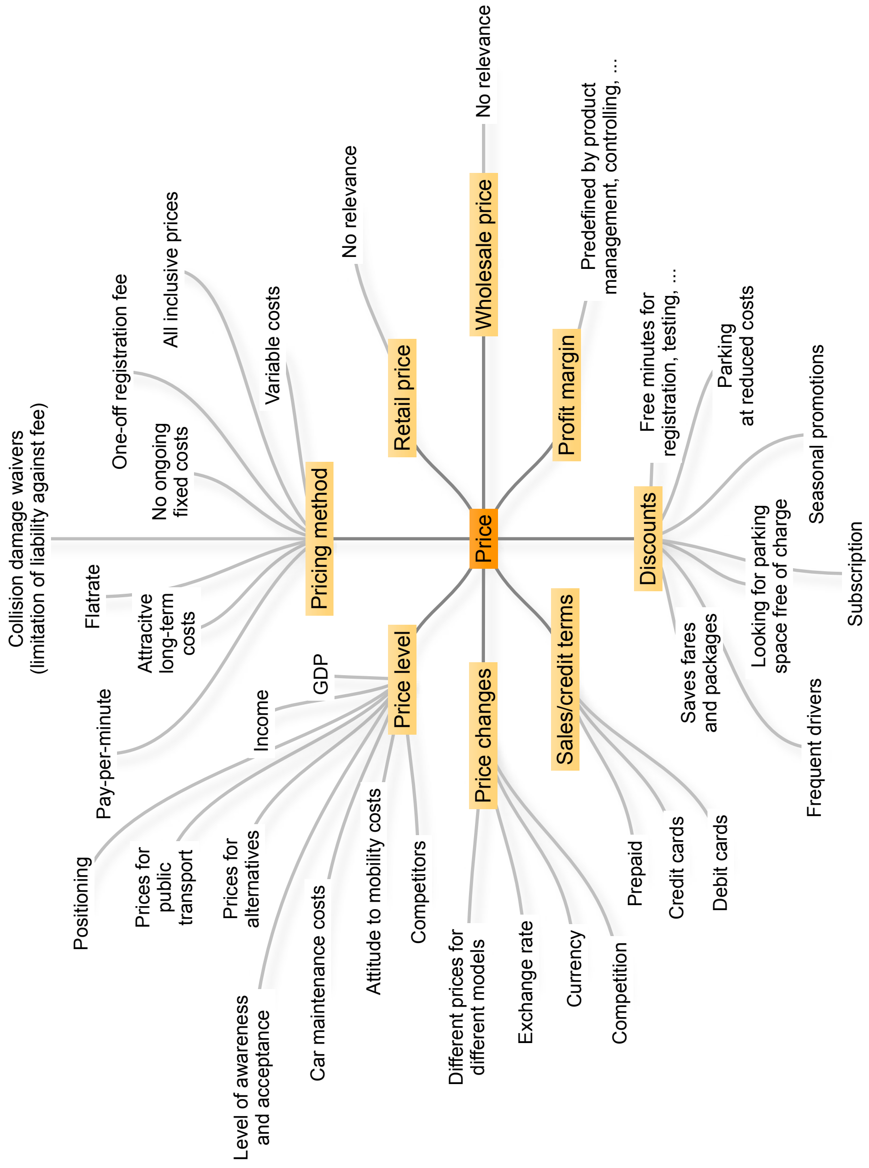


Figure A.4: Marketing Mix Element Price for Carsharing

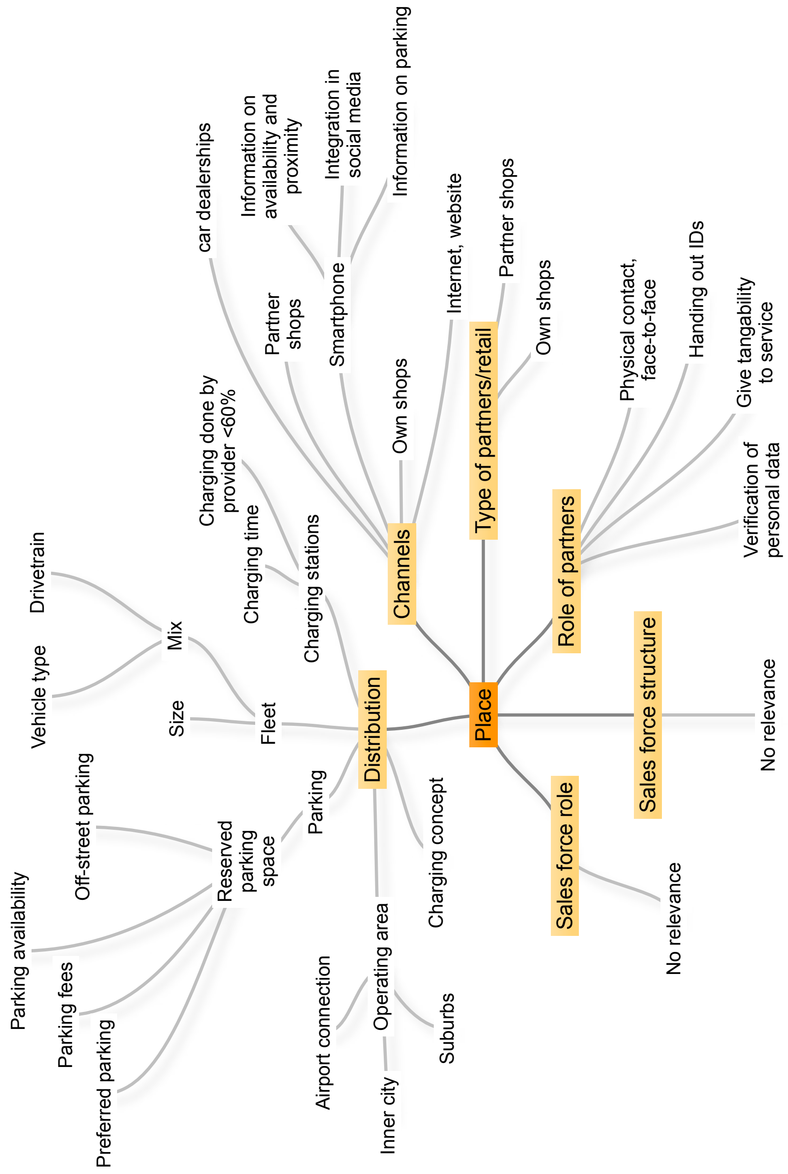


Figure A.5: Marketing Mix Element Place for Carsharing

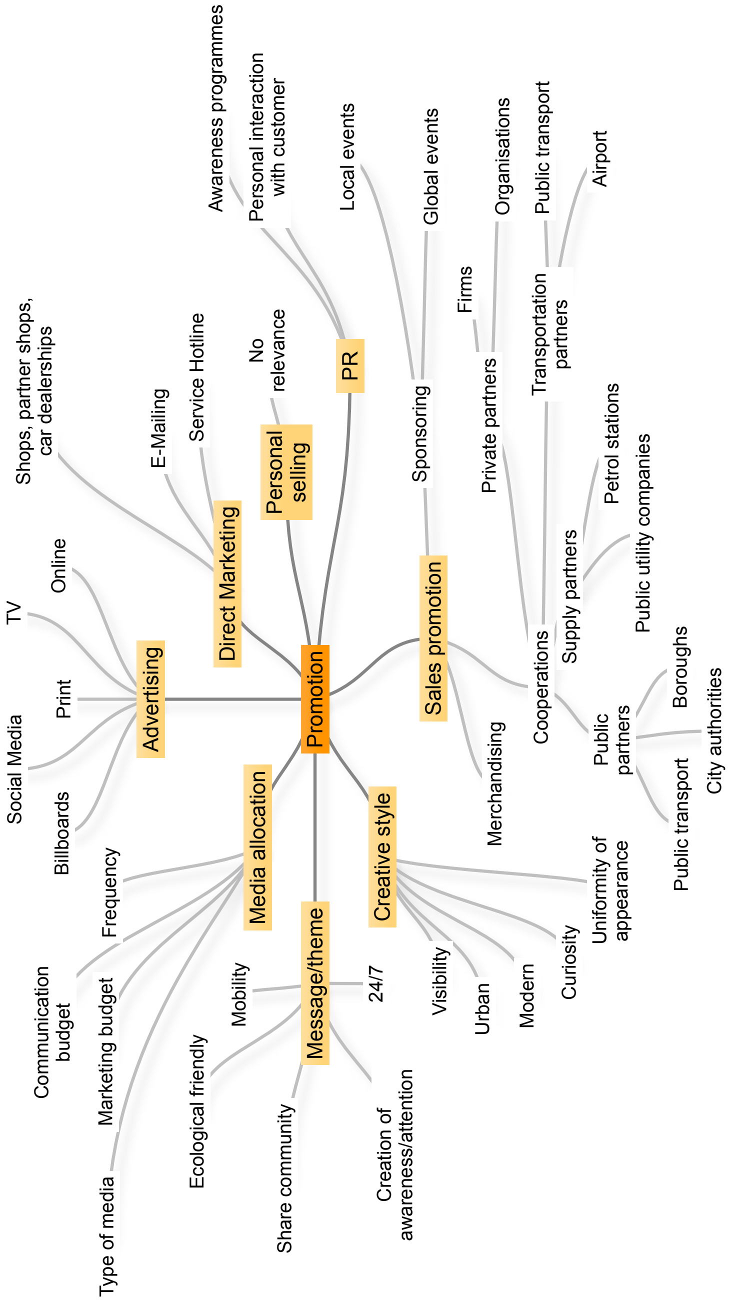


Figure A.6: Marketing Mix Element Promotion for Carsharing

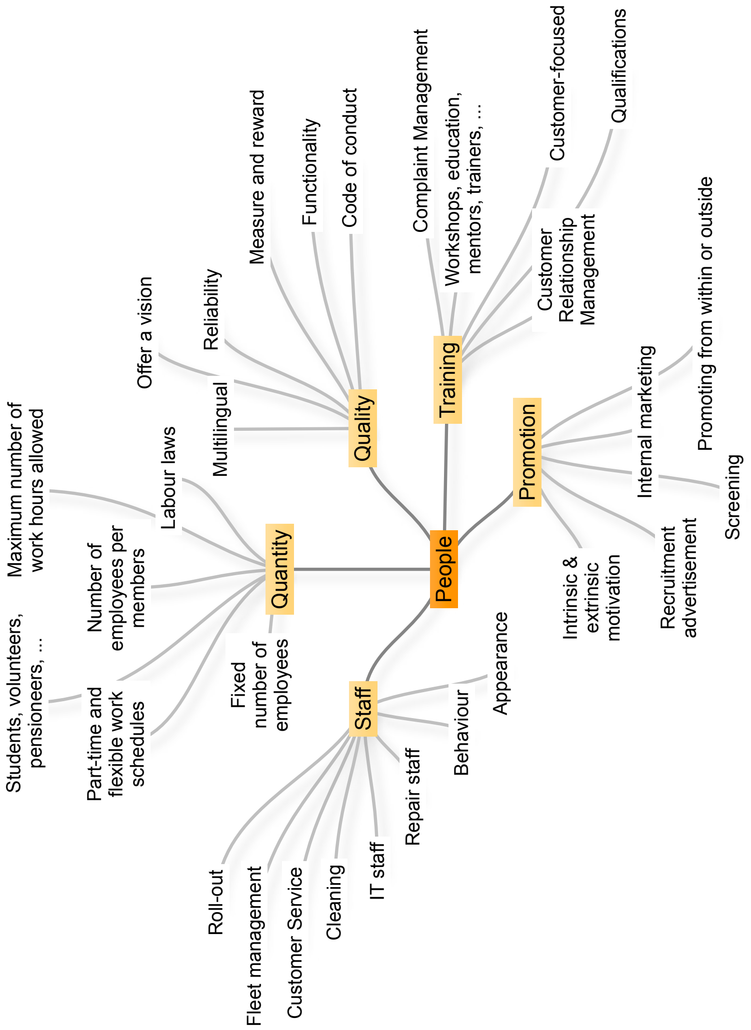


Figure A.7: Marketing Mix Element People for Carsharing

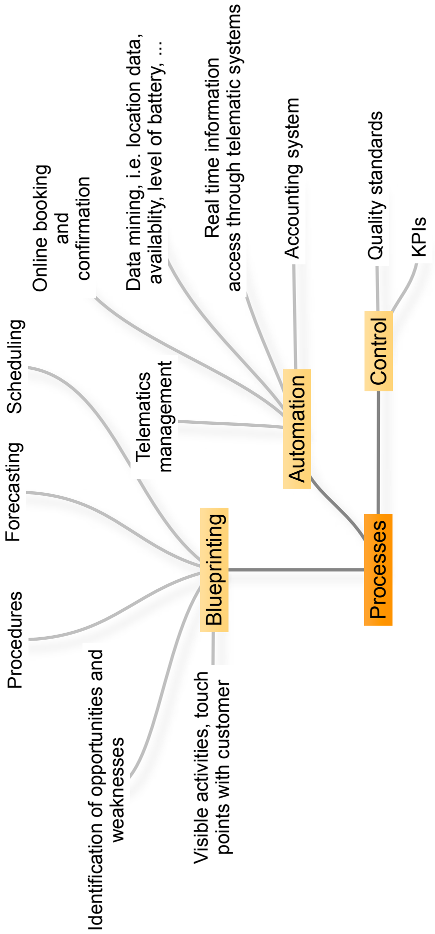


Figure A.8: Marketing Mix Element Processes for Carsharing

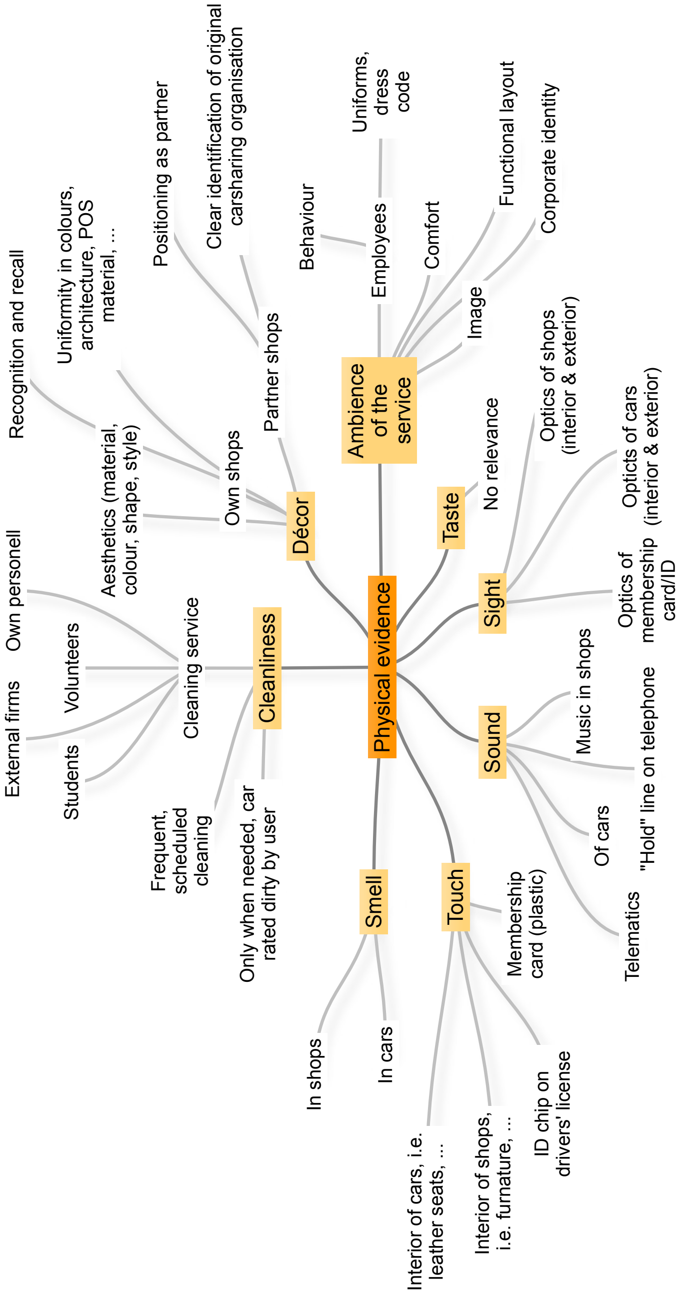


Figure A.9: Marketing Mix Element Physical Evidence for Carsharing

Appendix B

Overview of Selected Literature on Standardization and Adaptation

Table B.1: Overview of Selected Articles on Standardization and Adaptation. Adapted from [198]; own adjustments.

Source	Approach and Theoretical Basis	Theoretical Conclusion
Koh (1991) [127]	Quantitative testing of US exporters regarding: • Product • Price • Place • Promotion	Exporters, who are formally trained in international business, tend to charge higher prices for products exported than for sales in the domestic market. An often-modified product line leads to a higher perceived profitability. Adaptation to foreign market needs in terms of distribution and promotion is recommended due to differences in product usage, language and culture, and channel access.
Samiee and Roth (1992) [193]	Quantitative testing of: • Product • Price • Place • Promotion	In the absence of cross-national market segments, MNCs have to adapt their marketing strategies to foreign countries in order to discriminate prices and increase customer loyalty.

Table B.1: Continued

Source	**Approach and Theoretical Basis**	**Theoretical Conclusion**
Cavusgil and Zou (1994) [47]	Quantitative testing of: • Product • Promotion	MNCs have to adapt their products and communication to foreign countries in the situation of high international competence.
Shoham (1996) [217]	Quantitative testing of US exporters regarding: • Product • Price • Place • Promotion	MNCs have to adapt their marketing strategies to foreign countries in order to reduce friction between headquarters and foreign subsidiaries.
Littrell and Miller (2001) [141]	Rogers' Diffusion theory	MNCs have to adapt innovative products to foreign markets in order to decrease consumers' perceived complexity of the products and to increase consumers' perceived familiarity and compatibility with the products.
Vignali (2001) [247]	Analysis of McDonald's global marketing mix (7Ps)	Globalized organizations employ standardized products, promotional campaigns, prices, and distribution channels for all markets as if the world is one single entity. Brand name, product characteristics, packaging, and labeling are the easiest elements to be standardized. However, adjusting the marketing mix becomes vital in order to suit local tastes and meet special needs.

Table B.1: Continued

Source	**Approach and Theoretical Basis**	**Theoretical Conclusion**
Leonidou et al (2002) [139]	Literature review of articles and studies that assess export performance measurements	MNCs should adapt their international price levels, because export performance is strongly depending on pricing practices of competitors, purchasing power in the foreign country, costs of production, promotion, and transportation, as well as margins of distribution channels.
Lages and Jap (2002) [134]	Quantitative testing of Portuguese and Brazilian firms and theoretical consolidation: • Product • Price • Place • Promotion	MNCs standardize their products to offer competitive goods in export markets due to economies of scale. By adapting price, promotion, and place to differences in the political-legal, economic, and socio-cultural environment to any host country, firms can improve their performance significantly.
Vrontis (2003, 2005) [249, 250]	Qualitative testing of UK firms: • Product • Price • Place • Promotion • People • Processes • Physical Evidence	MNCs have to standardize their products in order to achieve uniformity in image, economies of scale, and consistency with consumers, as well as improved planning and controlling. Other elements have to be adapted to meet the differences that exist in the foreign country. The degree of standardization of the service focused Ps has to be balanced to ensure flexibility, but also the offering of a universal appeal.

Table B.1: Continued

Source	**Approach and Theoretical Basis**	**Theoretical Conclusion**
Stock-Homburg and Krohmer (2007) [228]	Quantitative testing across various branches for consumer goods in Germany	MNCs have to standardize their brands across nations in order to reduce consumer's uncertainty, to enhance a unified brand image, high brand recognition, and price advantages. Only a relatively high degree of standardization can lead to positive effects on a brand. Remaining below this certain degree means effects on the brand will be negative.

Appendix C

Detailed Analysis Report 1: Expert Opinions on Adapting the Carsharing Service Marketing Mix

Product

Brand Name: There is broad consensus among experts that brand name should be standardized. First however, in-depth investigations have to be conducted whether the name is legally protectable, culturally accepted, and not used by competitors already. The service and value proposition, which stands behind the name, must be identical in every city or country. Specialists see large multiplication and synergy effects resulting from a uniform brand name and appearance. If the core product is altered however, this might require brand name adaptation, e.g. when on-street parking is not possible and parking occurs in car parks only, then the name could be adapted so the consumer understands the altered concept better. Also, in Asia the name might have to be adapted due to the special letters, writing, and pronunciation.

Image: Most experts agree, ”image most definitely needs to be standardized. Through image the value of the brand is defined”. A consolidated and fixed brand core is key for the international and national roll-out of carsharing. Users of a mobility service like to hop from city to city and use the service wherever they are, hence a uniform brand image must be provided to create a constant message, and no need to explain the product over and over again. It is easier to position carsharing in a new country or city if the service already has an established and unchanged image. Also, a similar website contributes to the formal understanding of the concept. If a brand’s image is diffuse, it becomes very difficult to give the consumer orientation. Some respondents think that some adaptation is required, because in the various markets different brand values could be played or emphasized. So, image gives certain space to adjustment to specific local needs, target groups, or competitive conditions, e.g. in Russia sustainability does not play an important role as opposed to dynamics.

Quality: ”Without doubt and discussion, quality requires standardization.” All of the respondents share the opinion that carsharing must deliver an identical performance and service promise, as these support brand recognition and awareness effects. The qualitative promise entails the service’s availability and reliability. Also comfort and cleanliness are seen as basic quality expectations to be met worldwide.

Positioning: Positioning regarded as absolute characteristic should be identical, for example DriveNow as premium brand. For a brand with only one product, positioning and image are closely interlinked. The majority of experts come to the conclusion that positioning stands in between the two schools of thought. There is a set of product characteristics that are identical for every nation or city and on top there are additional attributes to suit the market, e.g. positioning as avant-garde brand for city dwellers or as eco-friendly alternative to the own car.

Performance: Almost all respondents are of the opinion that performance belongs to image, quality, and the central value proposition of free-floating carsharing, namely availability, flexibility, spontaneity, and the possibility of one-way trips. Hereafter, it needs to be standardized. Experts agree that carsharing members must experience the same level of performance everywhere, especially if they decide to go without their car. Otherwise, the brand might be damaged.

Variety, Design, Features: Design must be identical to achieve brand recognition and also visibility within the street scene. But ”cultural preferences and the diverse city structures call for an adjustment of the fleet.” Adaption regarding the drivetrain can be necessary due to local regulations such as emission limits or customer expectations. In some cities it might become mandatory to use electric vehicles to enter the city center for example. Regarding the vehicle types, the number of car models to choose from is added value for customers and there should always be a variety to choose from. In some contents however it might be necessary to adapt the kinds of vehicles used. Whereas the variety of models within one country is assumed to be more similar, because users might be quite identical when it comes to mobility needs, the fleet composition can always be tested with the existing local fleet mix. For instance, vehicles in the US are usually bigger than vehicles in Europe or Asia. When it comes to details (e.g. design, equipment), this is a cost-driven decision and it is indifferent from what a car manufacturer offers locally and therefore it can be neglected by carsharing providers.

Pre-sales Service: Pre-sales services include all sorts of information flows, customer care, and the accessibility to information prior to using carsharing. Processes behind the service should be facilitated everywhere and experts mainly agree on standardization. They feel confident that once the consumers know how carsharing works, they can hop around participating cities and always experience the same system, service, and value. On a national basis, pre-sales services should be the same, because there is only one website or smartphone app for information and use. Internationally, one parameter that requires adaption is language, but here one-to-one translation and a slightly adjusted tonality could be sufficient. Few understand pre-sales service as element to be adapted. They figure that channels are different depending on the country, e.g. Twitter must be used in the US whereas in Germany this is not standard. The same is true regarding registration outlet partners, which is discussed in chapter C, ”place”.

After-sales Service: The classification of after-sales services is dominated by opinions towards standardization. Particularly, if the driving of a car is considered a sale, after-sales services should be standardized, because the overall product experience should be the same. Consumers have to know what to expect before, during, and after usage. Carsharing has to be reliable and comfortable no matter where in the world as already indicated. Considering services like customer service or the hotline, experts agree that the way to interact with people must be customized, e.g. country-specific hotlines with staff that is familiar with local culture and language. It is a huge difference of how to speak to an American or German user and how to solve problems or, for example, some countries paperless invoicing is perceived as impersonal and of low customer care.

Packaging, Size: The element packaging is too expensive to be adapted to different countries. It should be treated like image and standardized according to the individual corporate identity. Packaging includes tools that consumers have to use in order to participate in carsharing. Especially interfaces should be standardized, as they are closely linked to how the service's quality is perceived.

Delivery, Installation: The philosophy of ”easy and intuitive handling” is seen as part of the core product; therefore, the majority of experts favor standardization for delivery and installation. The delivery of individual mobility is transmitted via app or the car as such and should contribute to an overall identical product experience.

Special attention has to be paid to technical processes that could require some form of adjustment due to different legal requirements, e.g. license verification as in some countries it is forbidden to verify a driver's license online.

Price

Pricing Method: Asked about the price element of carsharing, over half of the experts argue that a too strong dissection of the pricing structure takes negative effects on the consumers' price understanding. Pay-per-minute, rates for parking and stopovers, and all-inclusive prices are common practice for free-floating carsharing. To create understanding for the pricing method, consumers must recognize prices when using the service of one organization independent of their location. Other experts state that international adaptation of the pricing method could be important. The most prominent example where pricing is adjusted is the USA, because of their different habits, e.g. flat rates, inclusive minutes, and prices per hour. Here, a different method could be required due to the width of the cities and the country. Also competition plays a role in pricing and might influence national standards. In this early stage there might be room for experimenting, the more free-floating carsharing diffuses however, the more it will become synonym with pay-per-minute mobility.

Profit Margin: The profit margin must be the same everywhere according to the organization's strategic goals and its estimated revenue minus costs. Many specialists say, the margin is the result of the overall pricing strategy and not deliberately controlled. It should be the goal to have an equally high margin in every country, however price levels leverage the profit margin and so do local costs. Also, it is conditional to discounts, because large discounts reduce it. It is therefore a result of other pricing elements as well as to other elements that induce costs, such as the fleet mix or advertising, which are subject to adaptation.

Discounts: All experts questioned do not support full standardization of discount policies. Few think that a good balance of standardization and adaptation is necessary, because discounts are closely linked to positioning. Discounts are used to recruit new members, e.g. allow for free minutes or reduce the registration fee. The dominating opinion is that discounts have to be adjusted for every city in order to create incentives for locals. It is influenced by the product's lifecycle stage and its position compared to competitors. "Discounts are a tactical tool that require individual handling", says one of the experts.

Sales Terms: Even though the standardization of sales terms is a cost-driven decision, it is advisable to run the most common payment methods everywhere. For carsharing, credit card payment is common practice but offering more options to users helps the service to become more convenient. The majority of experts suggest a balance of the two schools of thought which also includes that terms and conditions require adjustment due to different regulations.

Price Changes: The majority argues that changes in price occur overtime and are an adaptation on international level. Here, prices cannot be decoupled from local competition or macroeconomic influences and happen individually. Changes also depend on a country's price elasticity and economic wealth in the respective market.

Price Level: There is wide agreement that within one country or even within one currency zone (Eurozone) prices should be the same, because members are mobile and expect transparent prices on their multiregional travels. Differences in local prices are difficult to justify and communicate, as worldwide usability and acceptability should be the goal. Experts and also theory come to the conclusion that international price levels should be adapted. For automobiles it is accepted to have a different pricing level throughout the world. If for example the general price level in Spain is lower than in Germany, at the end of the day, the business can still be profitable if local operating costs are lower than in Germany. Furthermore, in Asian markets, where being mobile and driving a car is associated with wealth, organizations could charge higher prices in order to justify the luxurious character.

Place

Distribution: ”Carsharing is always city-specific”, says one expert. Another explains: ”Carsharing does not cover all mobility needs as this is too expensive. Hence, basic mobility needs are covered by public transport, walking, or biking and in addition cars are used on a per minute basis”. All experts agree that distribution requires international and local adaptation of the operating area, fleet size, charging, and parking processes. The operating area demands for adjustments as every city's spatial extent differs. The fleet size depends on the size of the operating area, the larger the area the more cars are needed. The fleet mix as previously discussed not only depends on the local expectations but also on given charging infrastructures, i.e. an electric fleet would not make sense if there were no infrastructure. Charging processes applies for E-carsharing and organizations mostly have no influence on where stations are, as this is mainly a given condition by the city and also their technology differs from station to station. Accordingly, the charging concept or the way cars are charged must be locally adapted as well. In terms of parking, city specific parking allowances are required. In some cities, on-street parking would not be possible overall and partly and car parks are the only option altering the whole mobility concept. All these points are linked and depend on each other and it is the most prominent adaptation a carsharing organization has to do mandatorily.

Channels: Channels make a product and service available at appropriate times and places and for carsharing there is an overlap with distribution but also includes partner shops and outlets, the website, hotline, or smartphone app. Every country or city should have the same structure of channels, because they belong to the overall concept of carsharing as stated by the experts. The most important retail channel for carsharing is online, which brings the consumers to registration stations. The website is used for information needs and registration. The smartphone app is mainly used to find and book a car. However, as carsharing is offered with different business partners in different countries or even cities, distribution channels change and as a result require adaptation. For example, Sixt is BMW Group's joint venture partner for Europe, but when expanding to Japan potentially other business partners are needed since Sixt has no local presence.

Type of Partners: While it became apparent in other aspects that partners differ in an international context, this is confirmed explicitly by almost all experts. Local partners give a personalized look and feel to an international firm. The adaptation of type of partners is dependent to local conditions given in a country, e.g. other habits in terms of shopping, where to buy things, and the network or presence of the first-choice partner. Such a local partner must be willing to cooperate, fit the brand, and complement the organization with its know-how.

Role of Partners: As partners vary, also their individual roles are different because partners vary in their strengths and knowledge as well as their negotiation position. For joint ventures between car manufacturers and rental companies like car2go and DriveNow, roles are clearly separated and distributed to each associate. Car rental firms provide important back-end structures like invoicing or customer relationship management. They also share their in-depth knowledge in running car rentals, key management, and wide dealership networks. Even though standardization is desirable, it is very difficult to realize.

Promotion

Advertising: Most specialists agree that advertising channels should be adapted. For example social media channels require extreme customization, e.g. car2go has a separate Facebook page for each location. There is also a variety of different media in each city such as local newspapers or radio stations. Carsharing should look and feel like a city-specific service and personal contact to customers should be created. Also local features like the inclusion of an airport or furniture stores must be addressed in communication and advertising.

Direct Marketing: A standardized set of technical and procedural frameworks for direct marketing measurements is recommended by almost half of the experts. As direct marketing describes the interaction between the organization and consumers, face-to-face contacts via shops, the service hotline, mailings, and newsletters should be centrally directed. Specialists say that one cannot distinguish in which city the carsharing member is, because city hopping is common practice among urban people who share cars. Therefore, a call center, located somewhere in a country, must be able to answer any city-specific question. This is not a question of adaptation, as it is more attributable to trained staff. In a business where there are almost no physical consumer touch points, newsletters represent an obligation to update people, e.g. reminder to register, reminder to use the service again, extension of operating area, or special promotions. Its content should be city specific whereas the overall approach should be standardized. As a result, direct marketing is classified to be in the middle of standardization and adaptation.

PR: PR creates awareness, which contributes to sustainable changes in consumer behavior, i.e. away from owning a car to using and sharing it. A standardized set of topics to reach target groups should be given to all markets, as they have to align with the overall marketing strategy. In terms of carsharing, news directly affects car manufacturers behind the offer and therefore public communication is more standardized as it also shapes their image. One expert points out: ”PR is a central building block of the carsharing marketing mix, because these independent channels create more awareness than all other communication measurements”. When addressing city authorities, PR is to be adapted internationally and locally. The style of speech towards city authorities is very individual, as local needs, transportation policies, and legislations have to be considered. They require customized information and arguments. PR managers must be able to convince authorities why this form of new mobility benefits their city.

Sales Promotion: All in all, experts come to the conclusion that how promotion is done definitely varies. Every country or city has other events that could be featured and local partners for promotion differ as well, e.g. promotional activities with local IKEA stores, amusement parks, or day-trips to surrounding recreation areas. The standardized image and appearance should be assured in finding the right promotion partner.

Creative Style: All in all, experts argue interfaces and templates are standardized to create a uniform look and feel as well as a globally recognized brand, but some creative freedom should be given to the markets due to different formats or spelling. There is a standardized image and set of core values the provider stands for as well as a uniform corporate identity. On an international level, the majority of specialists refer to leanings gained from the automotive industry. Here, markets differ in the way a product is perceived, e.g. in some countries the car must be omnipresent and visible in all communications, whereas in other countries people, who drive the car should be the focus. Imagery must be adapted, just thinking about the question of whom the carsharing organization shows in their advertisements, i.e. color, gender, age, employment, stereotypes. Since carsharing is a very local product, experts also say that the way the brand speaks to consumers alternates city by city. Speaking the language of the local target group is important, as carsharing is a very local business. Car2go changes its style of speech according to every city's colloquial language, e.g. in Munich ”Servus Mnchen! Mia san hier!”.

Message/Theme: For carsharing, the message underlines the core propositions like mobility, availability, and spontaneity as well as it supports brand building by creating awareness and recognition. If the same product is internationalized, then the message should be the same. Also, since image and brand name are standardized, the communicative message should be identical too. A good example is Apple, which runs the same advertising at the same time in every market. Here, the creative style and message are identical. Speaking from practical experience, experts mention that a change in message does not occur too often, so sticking with one message is advised. More communication effort is needed for E-carsharing to reduce fear and make people curious about electromobility. Nevertheless, a balance of the two schools of thought is necessary because every city has its own problems, which need to be solved by new mobility concepts. With carsharing, it is desired to become part of the city and the organizations should take individual steps to make that happen. Additionally, if cities already have a vast offer of carsharing, new market entries must create and communicate unique selling propositions to better define their characteristics.

Media Allocation: Media allocation is the sharing of all media efforts on a global basis. Organizations concentrate on acquiring new customers, but this is difficult to achieve with above-the-line communication, as carsharing still is so innovative and new. Carsharing is focused around online communication and social media, but almost all experts agree that this element is to be adapted, because every country has its own budget and media mix.

Communication Budget: The communication budget is highly adaptive due to different media allocation and different media prices in the respective countries, e.g. Search Engine Optimization in the USA is more expensive than in Germany, due to more bids on the terms.

People

Quantity: Most experts agree that the quantity of operating staff is always adapted to the size of the respective city. The larger the operating area, the more staff is needed. So, depending on local structures the amount of people necessary could differ significantly. Culture has a lot do with how effective and diligent people work. Furthermore, the number of people hired in low-wage countries could be higher than in high-wage countries. Of course, if the business is growing, the quantity of employees needs to grow as well. Therefore, the quantity of people differs locally but is rather the result of other adaptions than an adaption itself.

Quality: Almost all experts share the opinion to standardize the quality of people working for a carsharing organization. They emphasize a service is just as good as the people delivering it. These people should have the same goals, vision, and service understanding. This can be derived from the standardized product quality and image.

Training: In terms of training most respondents argue that competencies should be identical all over the world. Additionally, since carsharing offers an identical product worldwide, product knowledge should be the same. This means providers would give out standardized quality and training handbooks or organize workshops and trainings with identical topics. Specialties to local conditions should be addressed by hiring locals who know best about local habits, infrastructures, etc.

Promotion: Carsharing is an innovative product that attracts many people, who want to work with it. Most experts argue that the technique of motivating people differs from country to country. In the beginning stage people desire to work with carsharing as they want to be part of the innovation and want to shape it. Also, in some countries headhunting is more pronounced or job applications are done via other platforms as commonly known in Germany, i.e. in person, acquaintance, online, intermediates. As a result, promotion is to be adapted.

Staff: The largest number of experts share the opinion that staff requires adaptation. They say: ”Staff must have country-specific knowledge and should be locally situated in order to develop a close customer relationship.” They emphasize the people component to be very important for carsharing, because a service is only as good as the people who create and deliver it. Users mainly have two touch points with staff, namely registration and the hotline if something goes wrong. Users feel better looked after by people in critical moments. Also, some countries are used to more personal care, hence more people are needed at contact points like partner shops. Apart from operations, all negotiation with city authorities is people’s business and requires careful selection of staff. As a result, the majority suggests a locally adapted composition of staff whilst roles can be the same or similar across countries and cities.

Processes

Blueprinting: Blueprinting is a uniform tactic for laying out how the service is delivered to the customer. Here, standardization potential is given, also before the background that a blueprint is a defined mean to establish standards. The operating blueprint must be standardized and transferred to new markets. The consistent process is needed in order to avoid additional costs for country specific adaptation, but probably requires some refinement. However, according to the experts free-floating carsharing is too new and blueprinting is not done yet.

Automation: ”Carsharing is to the highest level IT-oriented and if this whole system is not automated, something is done wrong”, says one of the experts. IT and telematics management will always be the same in every nation, therefore half of the experts believe that no adaptation is needed in terms of automation. Since automation is invisible for carsharing users, it should be a given standard for all processes that consumers do not perceive is essential. All other processes that are seen as beneficial and are key points should be handled with flexibility to incorporate rather quick changes and upcoming market demands. For example street distribution can be done with standardized fleet management software but manual inputs must be very city specific and require local knowledge. For example, cars being picked-up on a frequent basis at BMW Welt in Munich, but 400 meters further down at ”Olympiadorf” cars would be parked over days without intervention because parking facilities are rather grimy and dark. Such knowledge cannot be inherent in systems but require manual fine-tuning.

Control: The majority agrees on the standardization of control elements since common goals have to be fulfilled no matter where the service is operated. Organizations must establish tools and processes that are applicable everywhere, i.e. control KPIs or common quality management which also establishes comparability among countries and cities. However, globally valid KPIs require some adjustment from city to city, as not all global indicators can be fulfilled due to local conditions, i.e. the target met in one city could mean underperformance in another city.

Physical Evidence

Cleanliness: From quality standards derived functionality and comfort must be globally ensured and the level of cleanliness for carsharing should be standardized. In reality, cleanliness is perceived completely different from country to country and also (to a lesser degree) from city to city. For example, whereas in Mexico dusty and dirty foot mats are accepted, in Japan ideally every steering wheel would have to be sterilized after usage. As currently cleaning is done according to user ratings as well as to predefined schedules, the system is somewhat self-regulating and different perceptions are addressed. However, the perception of individuals is not within the control of the carsharing organizations.

Décor: The majority argues that all elements belonging to physical evidence of carsharing should be standardized, because they are ambassadors for the organizations' brand identity, architecture, and corporate identity. Referring to the automotive industry, car designers create vehicles for international tastes, e.g. a BMW 5 Series is seen just as dynamic and aesthetic in Canada, Germany, and China. Décor in this content is inked to the car and physical touch points consumers have when they want to use the service. At registration stations the décor is mostly not actively driven by the carsharing organization, and depends on the varying local partners. Nevertheless, movable walls or other décor elements should be standardized to enforce universal brand recognition.

Ambience of the Service: The ambience of the service is also referred to as ”look and feel” of the car, the service hotline, and customer care center. It is the first impression of a carsharing organization and significantly shapes the ambience of the service perceived by members. An equal opinion as with décor is shared, because the standardized ambience, aesthetics, and architecture are part of the brand's image and corporate identity, e.g. every Apple store or Hyatt hotel feels the same due to its style. Carsharing also has to establish the same experience no matter where the service is used.

Sound, Smell, Touch, and Sight: Sound, smell, touch, and sight are all human senses that are mainly activated by tangible elements of carsharing, namely the car as such. They underline the creation of physical evidence. In addition, senses are image factors addressing the emotional side of consumers in order to shape experiences. No matter where they are, consumers must get the feeling that the carsharing service is identical, as they perceive the same smell, sound, touch, and sight. International car manufacturers supply the cars used for carsharing and the vehicles have an original smell or sound as they come out of the production line. Almost all respondents agree that sensual elements are a standard created by production and cannot be altered to suit the desired sound of a particular city. If there are local alterations, e.g. no use of leather in Hindu countries, this would be addressed by the car supplier. Currently, operators do not actively play sounds or smells but if done this would also represent a company standard rather than local variations. Of course there is a different perception of e.g. pleasant fragrances between countries and a reactive adaptation as a consequence of local odors could be turned into a well-played marketing tool, similarly local sounds like samba rhythms could be played e.g. when starting the car as a temporary marketing gimmick.

Appendix D

Detailed Analysis Report 2: Qualitative Determination of Success Factors

Environmental Context

First, factors stemming from the *environmental context* are explained and according to theory geographical settings determine adoption. For carsharing it is suspected that adoption depends on where adopters live because mostly this is the starting- or end-point of a carsharing trip. Therefore, stakeholders agree that population density (1) is critical. To what extent absolute population (2) matters is perceived differently as free-floating services are currently limited to major cities and knowledge is limited. Additionally, it is relevant where people go. Mixed main movements within an area (3) are beneficial for carsharing because when area encompass a range of journey purposes, vehicles are utilized throughout the day by a variety of users and e.g. not only for commuting. Consequently, adoption happens in areas with a mixture of uses and is predetermined to urban areas and within these to city centers and sub-centers. The idea of carsharing entails not relying on private cars anymore. To do so reliably and cost-effectively, mobility needs are met by using multiple modes of transportation. An intermodal infrastructure is consequently vital for adoption and more specifically this includes the quality of public transportation, cycling infrastructure, and walkability (4, 5, 6) of an area. The latter two imply that topography (7) also plays a certain role in some areas. This means, where private cars are not used often enough, carsharing works. A factor that might obstruct private car-usage is the cost of parking (8) and parking availability (9). Here experts argue whether this is positive or negative as free-floating might be impacted negatively if providers do not solve this problem by acquiring parking licenses/spaces for their fleet. In the long run however, carsharing reduces private car-ownership and therefore also parking pressure should decrease. Another aspect influencing the necessity of a car is the spatial nature of a city, so a low average vehicle travel distance (10) is in favor of adoption. For example, this applies in Portland, Oregon (USA) where carsharing flourishes with the lowest mileage traveled per vehicle in the United States. The same is true for high traffic density (11) as people are more willing to give up their own car due to congestion or in tourism (12) regions where potential adopters come by train/airplane and cannot use their private car to travel locally. Furthermore, for E-carsharing access to a charging infrastructure (13) is important. Depending on range and usage, cars might not be charged daily but the better the infrastructure, the more adopters trust the system. This goes in hand with climate conditions (14) as too cold winters and too hot summers influence performance and range of BEVs noticeably as well as extreme weather discourages walking.

Next, factors regarding *societal culture* are examined and according to the interviewees, ownership/sharing is perceived differently. For example, in Swiss culture carsharing is perceived as favorable since ”sharing” is quite common, e.g. people share washing machines with their neighbors. Therefore, the status of ownership (15) and collectivism (16) play a role in the adoption of carsharing as well as the specific status of cars (17) and the status of public transportation (18). Additionally, knowledge about environmental issues or ecological awareness (19) and ecological friendliness (20) might motivate people to give up their cars. In general, also openness (21) and liberalism (22) within a culture influence whether innovations are adopted or not. Depending on the cars that are used in a carsharing system, not only the status of a car in general (17) but specifically the status of premium cars (23) differs within cultures as they might also be differently economically developed (24), which is an influential factor itself along with the living quality of an area (25). For example, in certain low-income and low living quality areas of Berlin or Paris cars (and premium cars in special) are prone to vandalism and in developing countries publicly available cars might be stolen for parts. A last cultural factor which is not specific to carsharing but for innovations in general is the perception of chances/risks and so the degree to which uncertainty avoidance (26) matters.

Following cultural factors, theory suggests that *political conditions* are influential for the adoption of innovations. When it comes to carsharing, regulations can help or prevent adoption, depending on cooperation. It is helpful for adoption that private car-ownership is disincentivized (27) and that carsharing receives non-financial incentives like designated parking in new housing projects (28), solutions for dedicated on-street parking (29), availability of public space (30), preferred parking (31), use of certain lanes (32) (bus or carpool lanes for example), or access to restricted areas (33) (e.g. city centers). Access to public parking is a prerequisite for free-floating carsharing offers to work, which stresses the importance of regulation. Similarly, also financial incentives can support adoption. Here factors like grants (34), tax breaks (35), free charging (36), exemptions from congestion charges or tolls (37), and purchase rebates (38) were mentioned. Furthermore, standardization of technological solutions (39) (e.g. for charging) and promotion efforts (40) such as in Karlsruhe, Germany, where the government acts as anchor adopter of E-carsharing, support adoption.

As next theoretical dimension within the environmental context *global uniformity* is explored. Here, mainly global trends were identified as factors for the adoption of carsharing: Rising oil prices (41) make private car-ownership unattractive whilst preferences change (42) and ownership becomes less important, leading to collaborative consumption and different status symbols. Similarly, sustainability (43) drives BEVs and the idea to replace cars. Another global trend is urbanization (44) which means more and more people move to cities and mobility concepts like carsharing become necessary to cope with the increased traffic, governmental regulations, and costs. Next, connectivity (45) is helpful for the adoption of carsharing as the diffusion of smartphones is a precondition for IT-based mobility services such as carsharing and the trend of increasing importance of convenience (46) means hassle-free services are increasingly preferred over products with ownership-duties. Moreover, growing individualization (47) leads to people differentiating themselves through innovations and boost their image through BEVs and the possibility to draw on a variety of cars. This is also caused through increased traveling (48), supporting the effectiveness of a global mobility service rather than relying on a relatively immobile private car.

The last and fifth dimension within the environmental context is *competition*. Most importantly, the existence of other car sharing companies (49) influences adoption. Here mainly innovation attributes matter (see below for details as this is an independent theoretical category) but the local existence can also help adoption since the concept is promoted by more entities and the existence of alternatives increases availability and reliability of the concept. Further, the cost of alternatives (50) can be differently structured and different price models increase the overall attractiveness of carsharing for more people and more use-cases. Furthermore, the adoption of carsharing also depends on the local cost of car rental (51), taxi (52) biking (53), sharing of private cars (54), peer-to-peer car sharing (55), carpooling (56), public transportation (57), and private cars (58).

A dimension that is not rooted in theory but appeared in interviews is *technology*, which can be reasonably grouped within the environmental context. Potential adopters might have certain expectations that influence their decision about whether to adopt. These expectations do not necessarily fit technological reality in a given context or market. In concrete terms, available technology influences charging time (59), the easiness of the charging process (60), costs of charging (61), availability of parking information (62), transparency about or easiness of the IT technology used (63), reliability of the IT technology (64), vehicle range (65), vehicle winter performance (66), vehicle functionality (67), vehicle reliability (68), and vehicle costs (69).

Adopter Characteristics

The next major component influencing the decision to adopt is adopter characteristics. Here, literature proposes that *familiarity with the innovation* is influential. In the case of carsharing however, adopters are usually unfamiliar with the innovation but they quickly understand the innovation because they were familiar with the technology used (70) (apps, internet) and their adoption decision is based on a word-of-mouth recommendation, because they are familiar with other users (71). This lowered their initial insecurity and consequently this was followed by an individual consideration if the concept pays.

Another proposition in the literature is *status characteristics* of adopters. However, it is not possible to determine an actor's relative position within a network in this research. In general, companies perceive the status of adopters as high (72).

Moreover, *socioeconomic characteristics* determine adoption. High education (73) appears crucial whether people adopt carsharing or not. The income is mixed (74), but above average, possibly related to education. Additionally, an adopter must have a driving license (75) and the size of the family (76) plays a role with one child being the likely limit. The age (77) of an adopter is young on average, but exceptions prove the rule. The interviewees were not in agreement about which gender (78) is influential for adoption. Some stated that typically men adopt whereas others said the opposite.

When it comes to *personal characteristics* of adopters, they are mostly described as technology affine (79), networked (80), communicative (81), open (82), ecologically aware (83), risk taking (84), confident (85), independent (86), and rational (87) as most adopters are driven by economic reasons.

Innovation Attributes

Innovation attributes is the third adoption determining category and is grouped into relative advantage, compatibility, complexity, trialability, and observability. First, the *relative advantage* of carsharing mostly refers to the comparison with private car-ownership but for some adopters the comparison is to not having access to cars at all using other alternatives such as public transport. For them, the possibility of accessing cars for transportation (88) is beneficial. Overall, the saving of money (89) (e.g. fixed costs, maintenance, gas, and parking fees) appears as the primary motivation, followed by comfort (90) and convenience (91) of the offer that saves time (92) in comparison with public transport. Additionally, there are no ownership duties (93) and carsharing can be used flexibly (94), spontaneously (95), and independently (96) from others. A further advantage is the possibility of access to a variety of cars (97). The powertrain of the car plays only a little role. BEVs only enhance the image (98) of the offer which is perceived as sustainable and innovative as well as they might help to benefit from regulatory advantages (99) (e.g. use of bus lanes). Ecological advantages (100) play only a secondary role for most people.

When it comes to *compatibility* to sociocultural values and beliefs, it was found that cars have to be modern (101), fun (102), well-equipped (103), and from a good brand (104). Furthermore, BEVs must be truly ”green” and charged with renewable energies (105). Additionally, cars must be well maintained as a prerequisite for safety and reliability (106). Adopters expect no commitment (107) (no base fees) and the possibility to plan/reserve (108) a car in advance as well as spontaneity (109) and flexibility (110). Furthermore, it is appreciated that carsharing creates social links/a community (111) e.g. by the integration of ridesharing or online-communities. Compatibility with previous adoptions and ideas is manifested in the following positions. First, E-carsharing cannot be worse in performance/comfort than conventional carsharing (112). Adopters do not accept compromises due to BEVs and expect the same functionality (trunk space, 4 seats) and performance (power, winter-performance). Furthermore, multimodal integration (113) must allow an easy transition between modes e.g. into public transport, bike-sharing, or car-rental. Ideally, the service shows alternatives and respective time, cost and ecological effects. Another point is the compatibility with phones (114) (e.g. for booking-app or personalization through integration in car-entertainment/navigation) and existing payment methods (115) as adopters do not want to change their habits. Compatibility of carsharing with client needs for the innovation is mainly assured through availability (116). Cars should be within 5-10min walking-distance. This is crucial for the offering, one (however station-based) provider reacts to this by giving a mobility guarantee and in case a reservation is canceled, mobility is guaranteed by taxi/public transport. Interestingly, this never happened but gives the adopter a feeling of safety. Having a premium 100% availability service for emergencies is a further option. Similarly, reliability of technology (117) and service (118) are necessities. This means adopters expect a car always to be charged (119) at least 60-70% to overcome range anxiety as well as reliable information about range (120). As with multimodality, adopters do not accept their mobility to be limited and expect big operating areas (121) that include airports and suburban areas and attractive pricing for longer-term use-cases (122) (e.g. daily/frequent-user rates). For many customers the purpose of car-usage only starts beyond these limits. The offer should also be available in as many cities (123) as possible to rely on it globally. The range of BEVs is perceived as sufficient for carsharing but can also be a limitation for some trips for which reason a mix of conventional-carsharing and E-carsharing (124) is preferred. Further, for free-floating concepts some reserved parking spaces (125) in dense areas and information on parking (126) and free-of-charge search for parking-spaces (127) are expected. However, this does not mean that free-floating is in disadvantage compared to traditional offers with a guaranteed parking space, as no fixed stations (128) allowing for one-way trips (129) are expected as well. Adopters rather want the best of both worlds, being flexible and allowed to go wherever needed whilst not worrying about parking. Finally, adopters expect cleanliness (130) and good support quality (131).

Low *complexity* is strongly valued by adopters. Primarily this concerns the ease of use (132), including simple handling (133) and simple charging, (134) for example inductive. One company provides free training (135) for BEVs, e.g. how to charge the car, alternatively also training on different car types is perceived useful. Additionally, transparency about price structure (136), limits of the operating area (137), parking (138), liability in case of damage (139), and range (140) are expected. The offering has the image of being complicated and there is little knowledge about it. Information and transparent communication (141) could help to change this. Lastly, registration (142) processes are complex and signing-up has to be easy, e.g. one company allows for registration at train stations or post offices through cooperation.

Trialability is relevant for new technology as people are curious about BEVs (143) and E-carsharing is a way to test them. In general, people appreciate the opportunity to test many different cars (144) but so far registration cost (145) is a hurdle to try the offer. Some companies offer trials (146) and introduction sessions (147) where the concept is explained and test drives are possible.

As the innovation is barely available yet, *observability* plays an important role. Potential adopters are afraid of the new technology, have range anxiety, and uncertainty must be overcome. One company approaches this by having on-street charging-stations (148) only and none in garages and they put their stations where visibility is guaranteed (149). This is a promising way as subtle appearance (150) as for example through inconspicuous stickers on cars is highly valued. Stakeholders agree that the biggest hurdle for the adoption of carsharing is little awareness (151) and understanding of the concept (152). Being observable is crucial and adopters should want to be observable and not feel ashamed.

Appendix E

Success Factor Overview and Argumentative Exploration

Qualitative Success Factors: What influences success?				Argumentative Exploration: To which factors must be locally adapted?			How can it be measured?	
No	**Theoretical Dimension**	**Category**	**Success Factor**	**Filter 1: Does this variable vary inbetween locations?**	**Filter 2: To ensure local inner-city adaptation (APPLICABILITY to existing cities), is it possible to break down the variable in small territorial units?**	**Result: Does the variable pass all argumentative filters with "yes"?**	**Indicator**	**Source**
1	Environmental Context	Geographical Settings	population density	yes	yes	yes	population density	Infas
2	Environmental Context	Geographical Settings	absolute poplation	yes	yes	yes	absolute poplation	Infas
3	Environmental Context	Geographical Settings	mixed main movements within an area	yes	yes	yes	company density centrality index rent index	Infas Infas Infas
4	Environmental Context	Geographical Settings	quality of public transportation, quality of cycling infrastructure, walkability (=intermodal infrastructure)	yes	yes	yes	station density	Open Street Map
5							distance to an ICE train station location index	Infas Infas
6							distance to the city center (town hall)	Open Street Map
7	Environmental Context	Geographical Settings	topography	yes	yes	yes	not applicable (in studied areas)	not available
8	Environmental Context	Geographical Settings	parking cost	yes	yes	yes	not available	not available
9	Environmental Context	Geographical Settings	parking availability	yes	yes	yes	not available	not available
10	Environmental Context	Geographical Settings	average vehicle travel distance	yes	yes	yes	frequent car user index	Infas
11	Environmental Context	Geographical Settings	traffic density	yes	yes	yes	not available	not available
12	Environmental Context	Geographical Settings	tourism	yes	yes	yes	restaurant and hotel density	Infas
13	Environmental Context	Geographical Settings	charging infrastructure	yes	yes	yes	not available	not available
14	Environmental Context	Geographical Settings	climate conditions	yes	no, city wide accuracy	no	-	-
15	Environmental Context	Societal Culture	status of ownership	yes	yes	yes	affinity for leasing index	Infas
16	Environmental Context	Societal Culture	collectivism	yes	yes	yes	not available	not available
17	Environmental Context	Societal Culture	status of cars	yes	yes	yes	used car ownership index	Infas
18	Environmental Context	Societal Culture	status of public transportation	yes	yes	yes	not available	not available
19	Environmental Context	Societal Culture	ecological awareness	yes	yes	yes	environmental affinity index	Infas
20							natural gas vehicle affinity index	Infas
21	Environmental Context	Societal Culture	openness	yes	yes	yes	factor innovation motivates consumption as index	Infas
22	Environmental Context	Societal Culture	liberalism	yes	yes	yes	lifestyle (six different types)	Infas
23	Environmental Context	Societal Culture	status of premium cars	yes	yes	yes	car engine power index	Infas
24	Environmental Context	Societal Culture	economic development	yes	yes	yes	purchasing power per capita index	Infas
25	Environmental Context	Societal Culture	living quality	yes	yes	yes	quality of residential area (six different classes)	Infas
26	Environmental Context	Societal Culture	uncertainty avoidance	yes	yes	yes	not available (only on country-level)	not available
27	Environmental Context	Political Conditions	private car ownership is disincentivised	yes	no, city wide accuracy	no	-	-
28	Environmental Context	Political Conditions	designated parking in new housing projects	yes	yes	yes	not applicable (not yet introduced in studied areas)	not available
29	Environmental Context	Political Conditions	solution for dedicated on-street parking	yes	no, city wide accuracy	no	-	-
30	Environmental Context	Political Conditions	availability of public space	yes	no, city wide accuracy	no	-	-
31	Environmental Context	Political Conditions	preferred parking	yes	no, city wide accuracy	no	-	-
32	Environmental Context	Political Conditions	use of certain lanes	yes	no, city wide accuracy	no	not applicable (not yet introduced in studied areas)	not available
33	Environmental Context	Political Conditions	access to restricted areas	yes	yes	yes	not applicable (not yet introduced in studied areas)	not available
34	Environmental Context	Political Conditions	grants	yes	no, city wide accuracy	no	-	-
35	Environmental Context	Political Conditions	tax breaks	yes	no, city wide accuracy	no	-	-
36	Environmental Context	Political Conditions	free charging	yes	no, city wide accuracy	no	-	-
37	Environmental Context	Political Conditions	exemption from congestion charges	yes	no, city wide accuracy	no	-	-

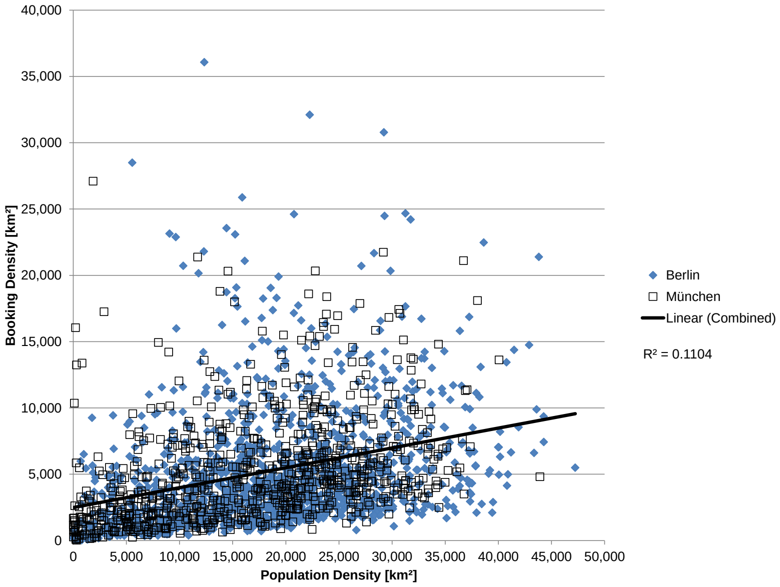
Qualitative Success Factors: What influences success?				Argumentative Exploration: To which factors must be locally adapted?			How can it be measured?	
No	**Theoretical Dimension**	**Category**	**Success Factor**	**Filter 1: Does this variable vary inbetween locations?**	**Filter 2: To ensure local inner-city adaptation (APPLICABILITY to existing cities), is it possible to break down the variable in small territorial units?**	**Result: Does the variable pass all argumentative filters with "yes"?**	**Indicator**	**Source**
38	Environmental Context	Political Conditions	purchase rebate	yes	no, city wide accuracy	**no**	-	-
39	Environmental Context	Political Conditions	standardisation	yes	no, country/state wide accuracy	**no**	-	-
40	Environmental Context	Political Conditions	promotion	yes	no, city wide accuracy	**no**	-	-
41	Environmental Context	Global Uniformity	oil price	no, global	-	**no**	-	-
42	Environmental Context	Global Uniformity	preference change	no, global	-	**no**	-	-
43	Environmental Context	Global Uniformity	sustainability	no, global	-	**no**	-	-
44	Environmental Context	Global Uniformity	urbanisation	no, global	-	**no**	-	-
45	Environmental Context	Global Uniformity	connectivity	no, global	-	**no**	-	-
46	Environmental Context	Global Uniformity	convenience	no, global	-	**no**	-	-
47	Environmental Context	Global Uniformity	individualisation	no, global	-	**no**	-	-
48	Environmental Context	Global Uniformity	increased travelling	no, global	-	**no**	-	-
49	Environmental Context	Competition	other car sharing companies	yes	no, city wide accuracy	**no**	-	-
50	Environmental Context	Competition	cost of alternatives	yes	no, city wide accuracy	**no**	-	-
51	Environmental Context	Competition	cost of car rental	yes	no, city wide accuracy	**no**	-	-
52	Environmental Context	Competition	cost of taxi	yes	no, city wide accuracy	**no**	-	-
53	Environmental Context	Competition	cost of biking	yes	no, city wide accuracy	**no**	-	-
54	Environmental Context	Competition	cost of sharing of private cars	yes	no, city wide accuracy	**no**	-	-
55	Environmental Context	Competition	cost of peer-to-peer car sharing	yes	no, city wide accuracy	**no**	-	-
56	Environmental Context	Competition	cost of carpooling	yes	no, city wide accuracy	**no**	-	-
57	Environmental Context	Competition	cost of public transportation	yes	no, city wide accuracy	**no**	-	-
58	Environmental Context	Competition	cost of private cars	yes	no, city wide accuracy	**no**	-	-
59	Environmental Context	Available Technology	charging time	no, global	-	**no**	-	-
60	Environmental Context	Available Technology	easy charging process	no, global	-	**no**	-	-
61	Environmental Context	Available Technology	cost of charging	no, global	-	**no**	-	-
62	Environmental Context	Available Technology	availability of parking information	no, global	-	**no**	-	-
63	Environmental Context	Available Technology	transparency about the IT technology	no, global	-	**no**	-	-
64	Environmental Context	Available Technology	reliability of the IT technology	no, global	-	**no**	-	-
65	Environmental Context	Available Technology	vehicle range	no, global	-	**no**	-	-
66	Environmental Context	Available Technology	vehicle winter performance	no, global	-	**no**	-	-
67	Environmental Context	Available Technology	vehicle functionality	no, global	-	**no**	-	-
68	Environmental Context	Available Technology	vehicle reliability	no, global	-	**no**	-	-
69	Environmental Context	Available Technology	vehicle cost	no, global	-	**no**	-	-
70	Adopter Characteristics	Familiarity with the innovation	Familiarity with the technology	yes	yes	yes	not available (only on city-level)	not available
71	Adopter Characteristics	Familiarity with the innovation	Familiarity with other users	yes	yes	yes	not available (only on city-level)	not available
72	Adopter Characteristics	Status Characteristics	high status	yes	yes	yes	social class (five classes)	Infas
73	Adopter Characteristics	Socioeconomic Characteristics	high education	yes	yes	yes	student density (education is only available on city level)	Infas
74	Adopter Characteristics	Socioeconomic Characteristics	mixed income	yes	yes	yes	household net incomes (five classes)	Infas
75	Adopter Characteristics	Socioeconomic Characteristics	driving license	yes	yes	yes	car density	Infas
76	Adopter Characteristics	Socioeconomic Characteristics	family size	yes	yes	yes	one person households two person households three or more person households avergae household size one child households	Infas Infas Infas Infas Infas

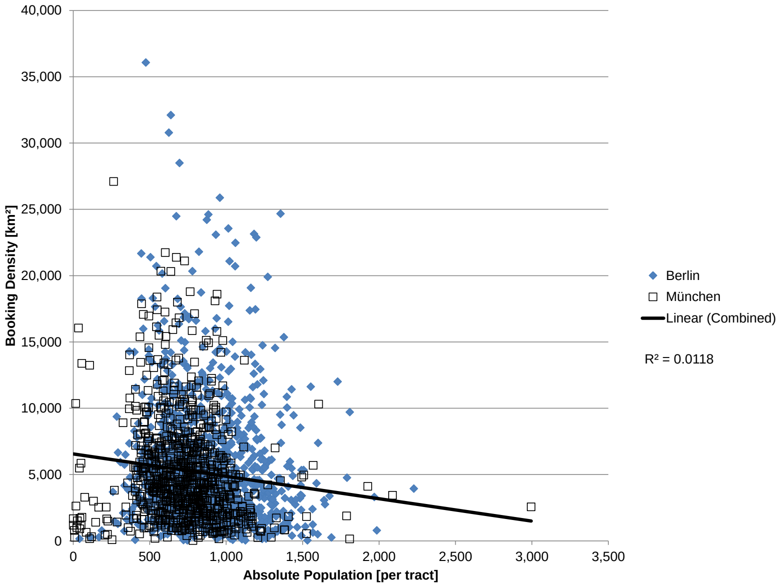
Qualitative Success Factors: What influences success?				Argumentative Exploration: To which factors must be locally adapted?			How can it be measured?	
No	**Theoretical Dimension**	**Category**	**Success Factor**	**Filter 1: Does this variable vary inbetween locations?**	**Filter 2: To ensure local inner-city adaptation (APPLICABILITY to existing cities), is it possible to break down the variable in small territorial units?**	**Result: Does the variable pass all argumentative filters with "yes"?**	**Indicator**	**Source**
77	Adopter Characteristics	Socioeconomic Characteristics	age	yes	yes	yes	two children households three or more children households population age (five classes)	Infas Infas Infas
78	Adopter Characteristics	Socioeconomic Characteristics	gender	yes	yes	yes	not applicabel as gender is equally distributed in studied areas	not available
79	Adopter Characteristics	Personal Characteristics	technology affine	yes	yes	yes	UMTS affinity index high-tech affinity index	Infas Infas
80, 81, 82	Adopter Characteristics	Personal Characteristics	networked, communicative, open	yes	yes	yes	telecommunication types (three types)	Infas
83	Adopter Characteristics	Personal Characteristics	ecologically aware	yes	yes	yes	factor environment motivates consumption as index	Infas
84	Adopter Characteristics	Personal Characteristics	risk taking	yes	yes	yes	not available	not available
85	Adopter Characteristics	Personal Characteristics	confident	yes	yes	yes	factor brand motivates consumption as index	Infas
86	Adopter Characteristics	Personal Characteristics	independent	yes	yes	yes	YUPPIE density	Infas
87	Adopter Characteristics	Personal Characteristics	rational	yes	yes	yes	factor price motivates consumption as index	Infas
88	Innovation Attribute	Relative Advantage	posibility to use cars for transportation	no, concept inherent	-	**no**	-	-
89	Innovation Attribute	Relative Advantage	saving of money	no, concept inherent	-	**no**	-	-
90	Innovation Attribute	Relative Advantage	comfort	no, concept inherent	-	**no**	-	-
91	Innovation Attribute	Relative Advantage	convenience	no, concept inherent	-	**no**	-	-
92	Innovation Attribute	Relative Advantage	saving of time	no, concept inherent	-	**no**	-	-
93	Innovation Attribute	Relative Advantage	no ownership duties	no, concept inherent	-	**no**	-	-
94	Innovation Attribute	Relative Advantage	flexible	no, concept inherent	-	**no**	-	-
95	Innovation Attribute	Relative Advantage	spontaneous	no, concept inherent	-	**no**	-	-
96	Innovation Attribute	Relative Advantage	independent	no, concept inherent	-	**no**	-	-
97	Innovation Attribute	Relative Advantage	variety of cars	no, concept inherent	-	**no**	-	-
98	Innovation Attribute	Relative Advantage	image	no, concept inherent	-	**no**	-	-
99	Innovation Attribute	Relative Advantage	benefit from regulatory advantages	no, concept inherent	-	**no**	-	-
100	Innovation Attribute	Relative Advantage	ecological adavantages	no, concept inherent	-	**no**	-	-
101	Innovation Attribute	Compatibility	modern cars	no, concept inherent	-	**no**	-	-
102	Innovation Attribute	Compatibility	fun cars	no, concept inherent	-	**no**	-	-
103	Innovation Attribute	Compatibility	well-equipped cars	no, concept inherent	-	**no**	-	-
104	Innovation Attribute	Compatibility	brand of the cars	no, concept inherent	-	**no**	-	-
105	Innovation Attribute	Compatibility	cars must be charged with renewable energies	no, concept inherent	-	**no**	-	-
106	Innovation Attribute	Compatibility	well maintained cars	no, concept inherent	-	**no**	-	-
107	Innovation Attribute	Compatibility	no commitment	no, concept inherent	-	**no**	-	-
108	Innovation Attribute	Compatibility	possibility to plan	no, concept inherent	-	**no**	-	-
109	Innovation Attribute	Compatibility	spontaneity	no, concept inherent	-	**no**	-	-
110	Innovation Attribute	Compatibility	flexibility	no, concept inherent	-	**no**	-	-
111	Innovation Attribute	Compatibility	community membership	no, concept inherent	-	**no**	-	-
112	Innovation Attribute	Compatibility	BEVs cannot perform worse than ICEs	no, concept inherent	-	**no**	-	-
113	Innovation Attribute	Compatibility	multimodal integration	no, concept inherent	-	**no**	-	-
114	Innovation Attribute	Compatibility	phone compatibility	no, concept inherent	-	**no**	-	-
115	Innovation Attribute	Compatibility	payment methods	no, concept inherent	-	**no**	-	-
116	Innovation Attribute	Compatibility	availability	no, concept inherent	-	**no**	-	-

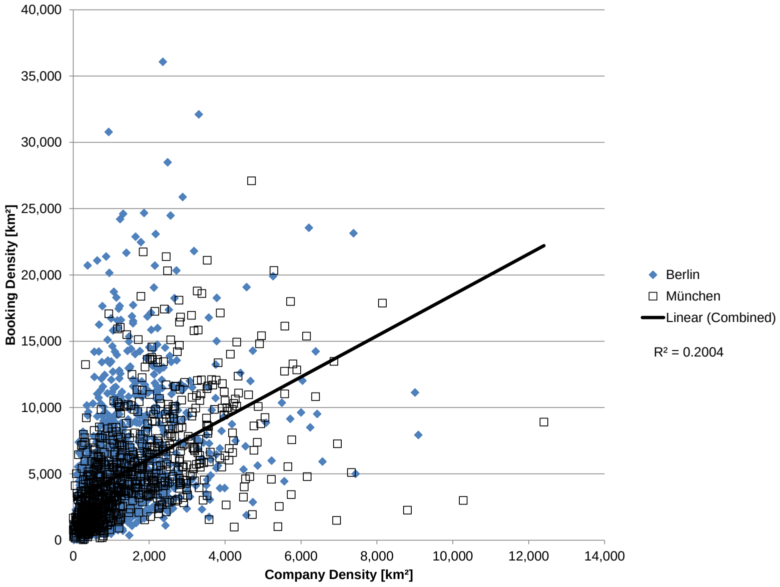
Qualitative Success Factors: What influences success?				Argumentative Exploration: To which factors must be locally adapted?			How can it be measured?	
No	Theoretical Dimension	Category	Success Factor	Filter 1: Does this variable vary inbetween locations?	Filter 2: To ensure local inner-city adaptation (APPLICABILITY to existing cities), is it possible to break down the variable in small territorial units?	Result: Does the variable pass all argumentative filters with "yes"?	Indicator	Source
117	Innovation Attribute	Compatibility	reliable technology	no, concept inherent	-	**no**	-	-
118	Innovation Attribute	Compatibility	reliable service	no, concept inherent	-	**no**	-	-
119	Innovation Attribute	Compatibility	charged cars	no, concept inherent	-	**no**	-	-
120	Innovation Attribute	Compatibility	reliable information about range	no, concept inherent	-	**no**	-	-
121	Innovation Attribute	Compatibility	big operating areas	no, concept inherent	-	**no**	-	-
122	Innovation Attribute	Compatibility	attractive long-term pricing	no, concept inherent	-	**no**	-	-
123	Innovation Attribute	Compatibility	global offer in many cities	no, concept inherent	-	**no**	-	-
124	Innovation Attribute	Compatibility	mix of electric and conventional vehicles	no, concept inherent	-	**no**	-	-
125	Innovation Attribute	Compatibility	reserved parking spaces	no, concept inherent	-	**no**	-	-
126	Innovation Attribute	Compatibility	information on parking	no, concept inherent	-	**no**	-	-
127	Innovation Attribute	Compatibility	free looking for parking spaces	no, concept inherent	-	**no**	-	-
128	Innovation Attribute	Compatibility	no fixed stations	no, concept inherent	-	**no**	-	-
129	Innovation Attribute	Compatibility	one-way trips	no, concept inherent	-	**no**	-	-
130	Innovation Attribute	Compatibility	cleanliness	no, concept inherent	-	**no**	-	-
131	Innovation Attribute	Compatibility	support quality	no, concept inherent	-	**no**	-	-
132	Innovation Attribute	Complexity	ease of use	no, concept inherent	-	**no**	-	-
133	Innovation Attribute	Complexity	simple handling	no, concept inherent	-	**no**	-	-
134	Innovation Attribute	Complexity	simple charging	no, concept inherent	-	**no**	-	-
135	Innovation Attribute	Complexity	training	no, concept inherent	-	**no**	-	-
136	Innovation Attribute	Complexity	transparent price structure	no, concept inherent	-	**no**	-	-
137	Innovation Attribute	Complexity	transparent limits of the operating area	no, concept inherent	-	**no**	-	-
138	Innovation Attribute	Complexity	transparent parking rules	no, concept inherent	-	**no**	-	-
139	Innovation Attribute	Complexity	transparent liability in case of damage	no, concept inherent	-	**no**	-	-
140	Innovation Attribute	Complexity	transparent range	no, concept inherent	-	**no**	-	-
141	Innovation Attribute	Complexity	transparent communication	no, concept inherent	-	**no**	-	-
142	Innovation Attribute	Complexity	easy registration process	no, concept inherent	-	**no**	-	-
143	Innovation Attribute	Trialability	curiousity about electric vehicles	no, concept inherent	-	**no**	-	-
144	Innovation Attribute	Trialability	possibility to test a variety of cars	no, concept inherent	-	**no**	-	-
145	Innovation Attribute	Trialability	registration cost as hurdle	no, concept inherent	-	**no**	-	-
146	Innovation Attribute	Trialability	trial sessions	no, concept inherent	-	**no**	-	-
147	Innovation Attribute	Trialability	introdction sessions	no, concept inherent	-	**no**	-	-
148	Innovation Attribute	Observability	on-street charging stations	no, concept inherent	-	**no**	-	-
149	Innovation Attribute	Observability	visible location of stations	no, concept inherent	-	**no**	-	-
150	Innovation Attribute	Observability	subtle appearance	no, concept inherent	-	**no**	-	-
151	Innovation Attribute	Observability	awareness of the concept	no, concept inherent	-	**no**	-	-
152	Innovation Attribute	Observability	understanding of the concept	no, concept inherent	-	**no**	-	-

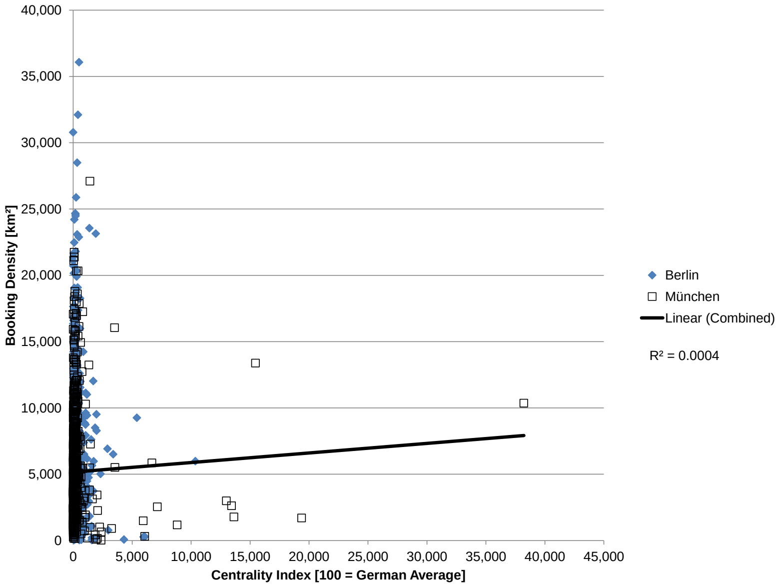
Appendix F

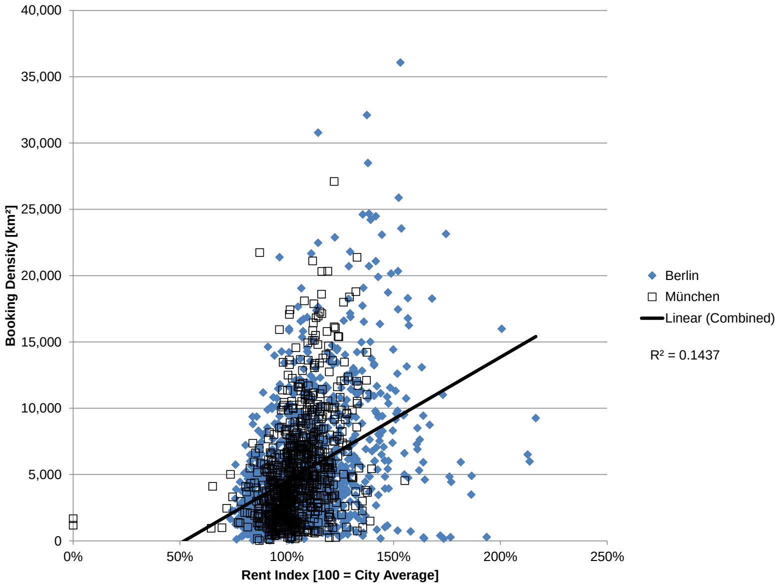
Scatter Plots for the Quantitative Determination of Success Factors

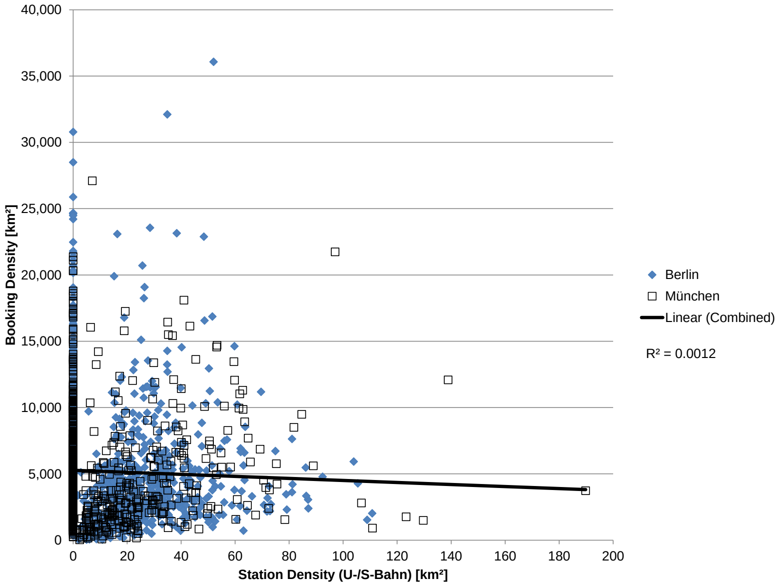

Booking Density [km²]
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
Population Density [km²]
Berlin
München
Linear (Combined)
R² = 0.1104

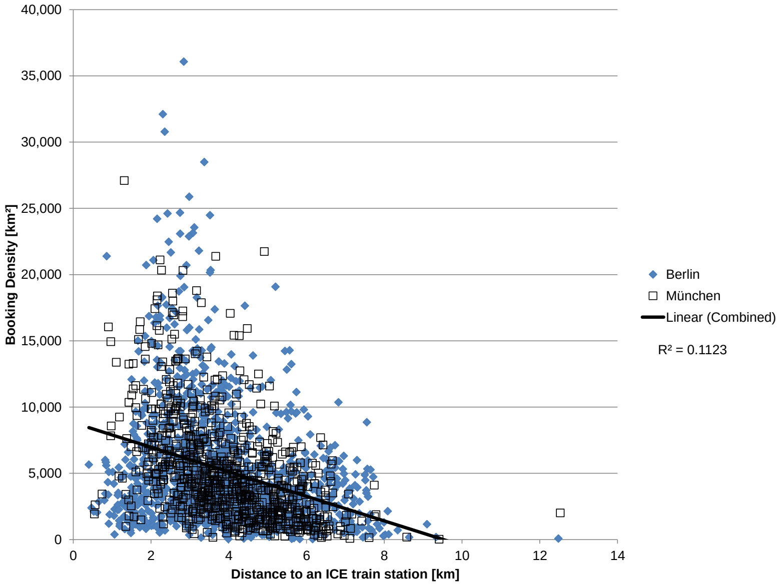

Booking Density [km²]
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Absolute Population [per tract]
Berlin
München
Linear (Combined)
R² = 0.0118

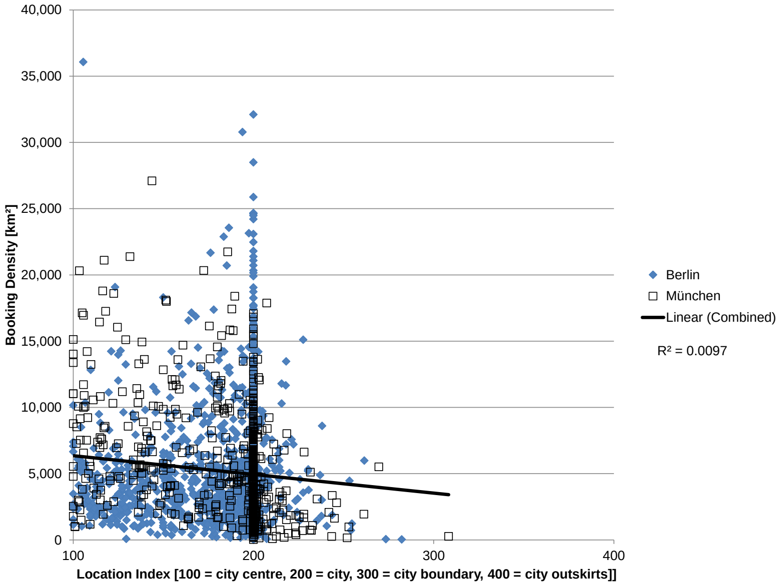

Booking Density [km²]
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Company Density [km²]
Berlin
München
Linear (Combined)
R² = 0.2004

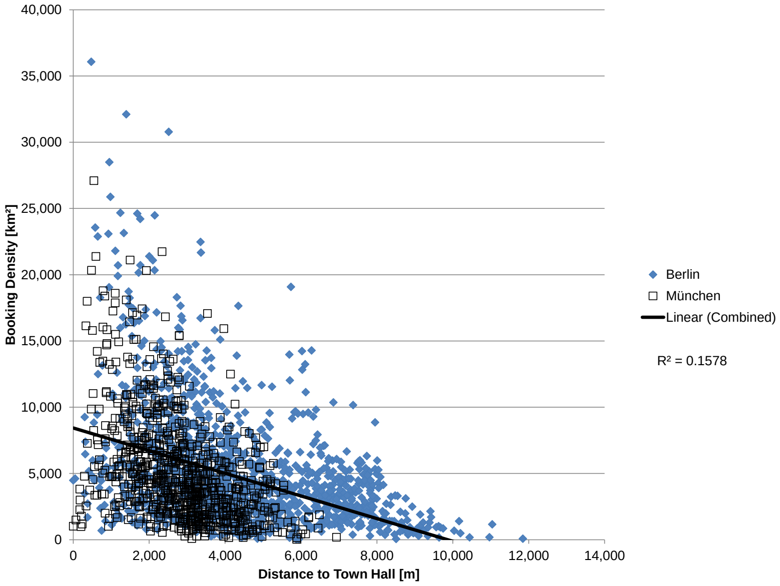

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Centrality Index [100 = German Average]
Berlin
München
Linear (Combined)
R² = 0.0004

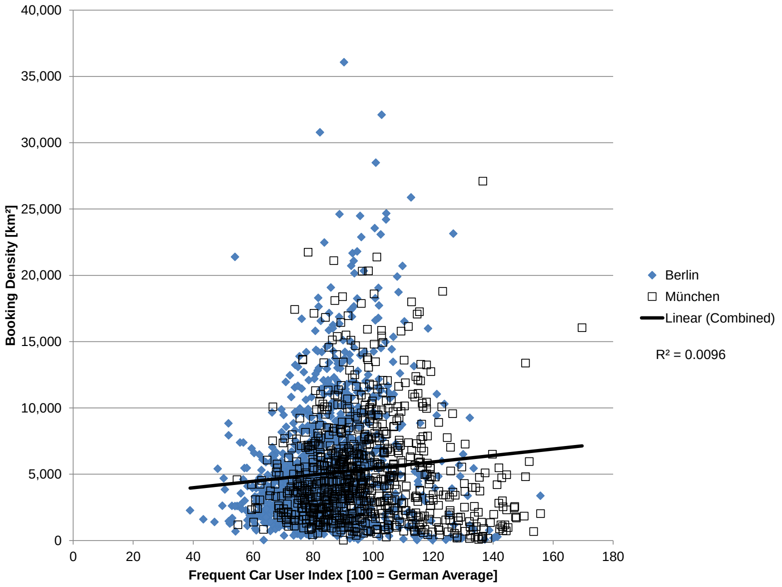

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
50%
100%
150%
200%
250%
Rent Index [100 = City Average]
Berlin
München
Linear (Combined)
R² = 0.1437

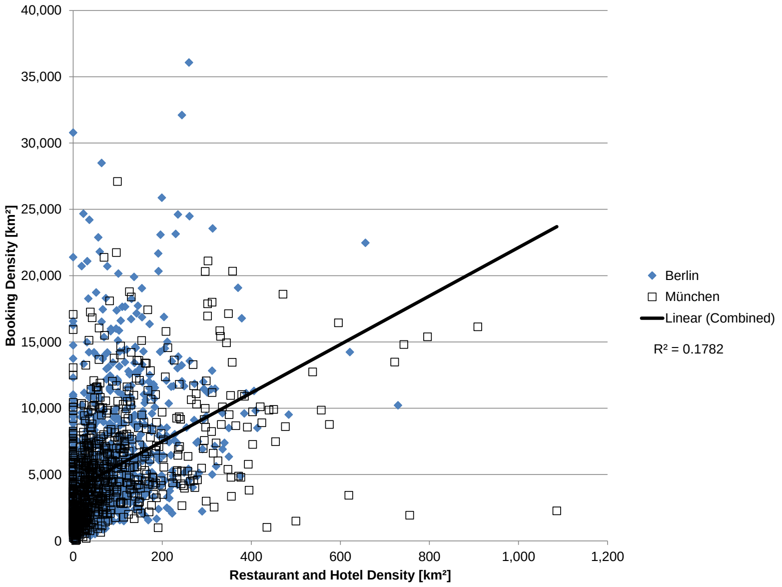

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
200
Station Density (U-/S-Bahn) [km²]
Berlin
München
Linear (Combined)
R² = 0.0012

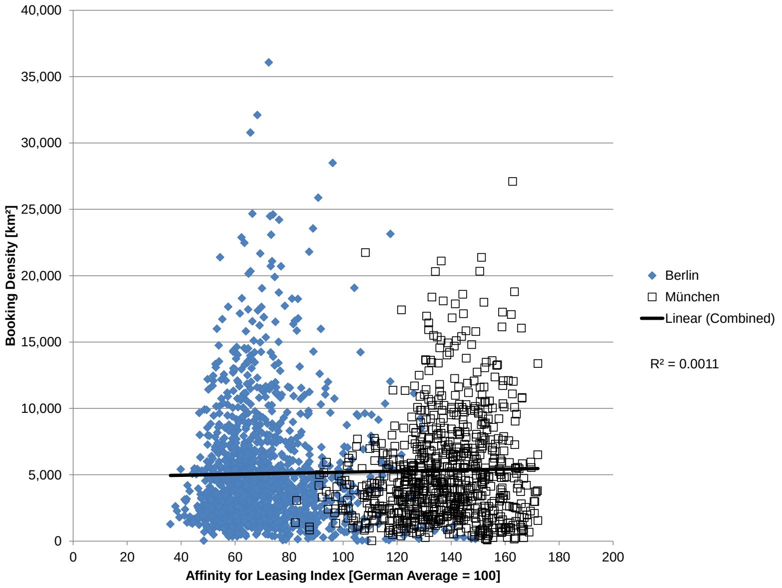

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
2
4
6
8
10
12
14
Distance to an ICE train station [km]
Berlin
München
Linear (Combined)
R² = 0.1123

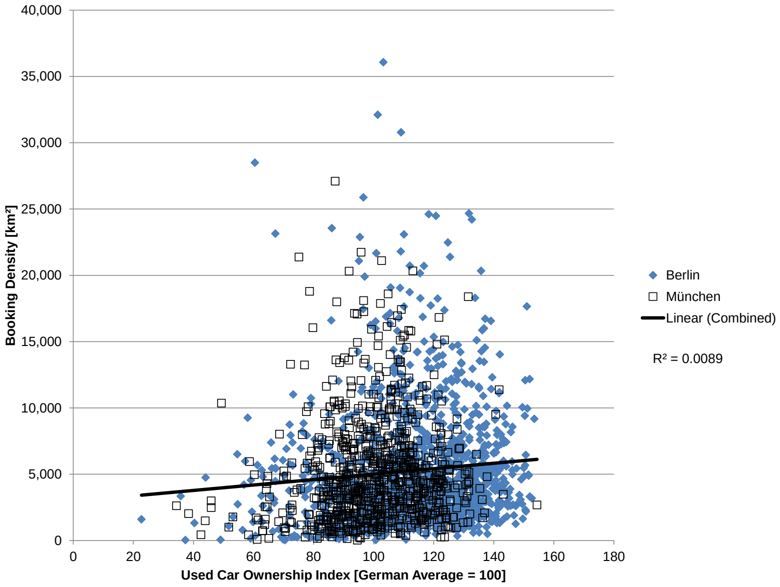

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
100
200
300
400
Location Index [100 = city centre, 200 = city, 300 = city boundary, 400 = city outskirts]]
Berlin
München
Linear (Combined)
R² = 0.0097

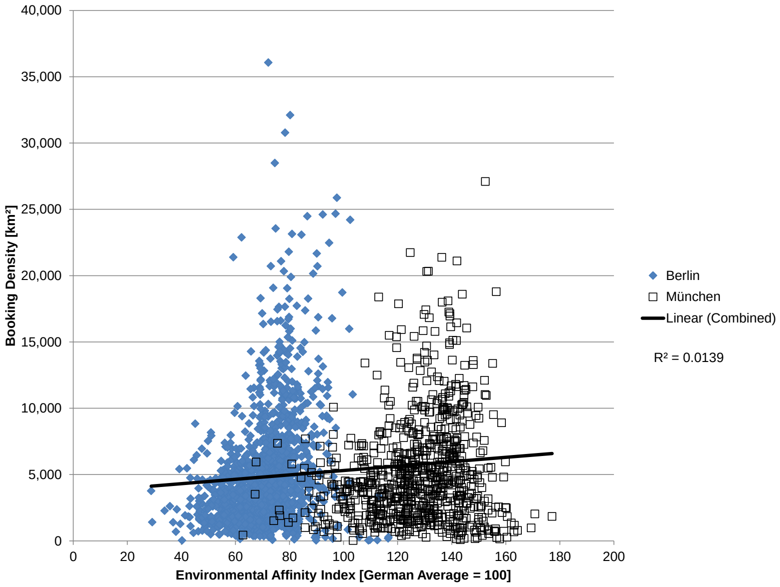

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Distance to Town Hall [m]
Berlin
München
Linear (Combined)
R² = 0.1578

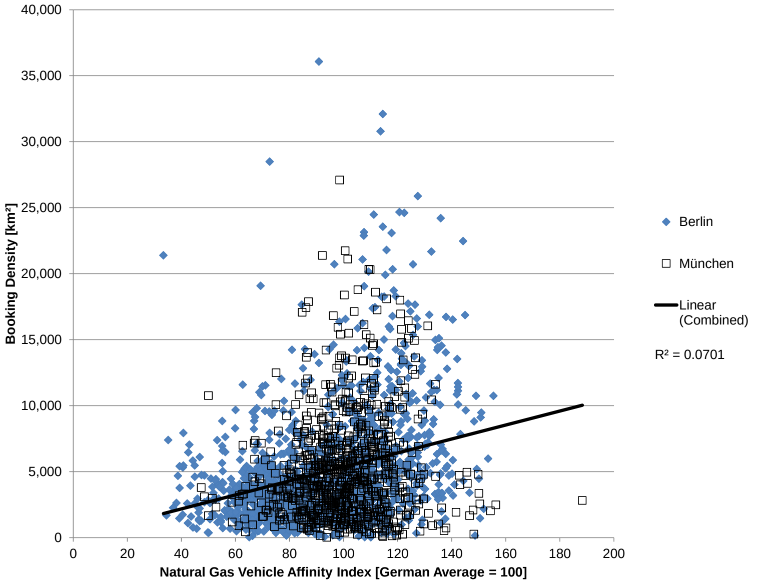

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
Frequent Car User Index [100 = German Average]
Berlin
München
Linear (Combined)
R² = 0.0096

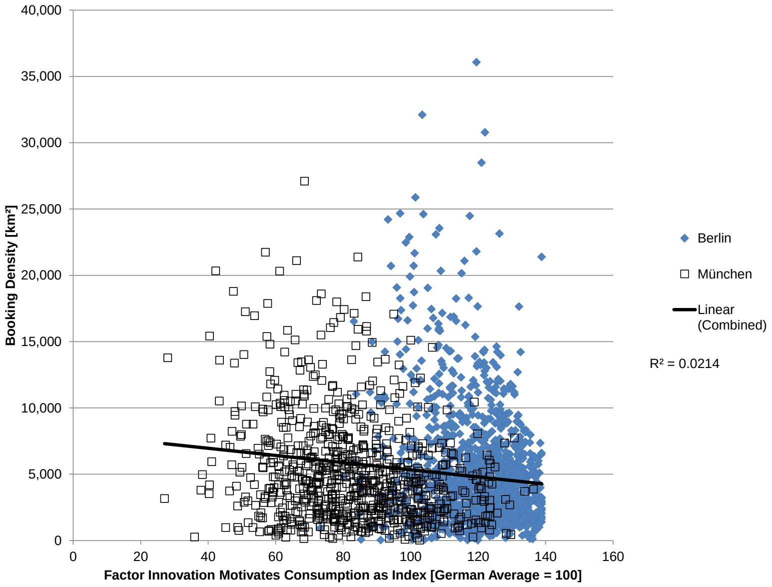

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
200
400
600
800
1,000
1,200
Restaurant and Hotel Density [km²]
Berlin
München
Linear (Combined)
R² = 0.1782

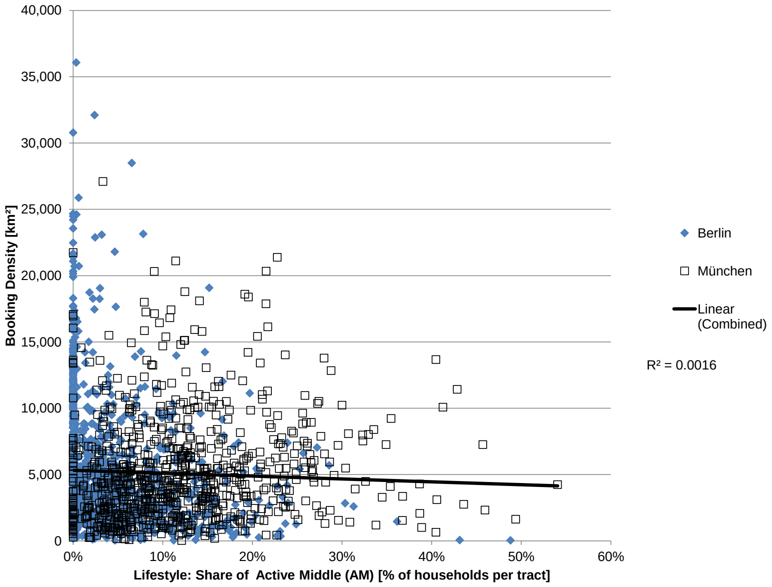

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
200
Affinity for Leasing Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0011

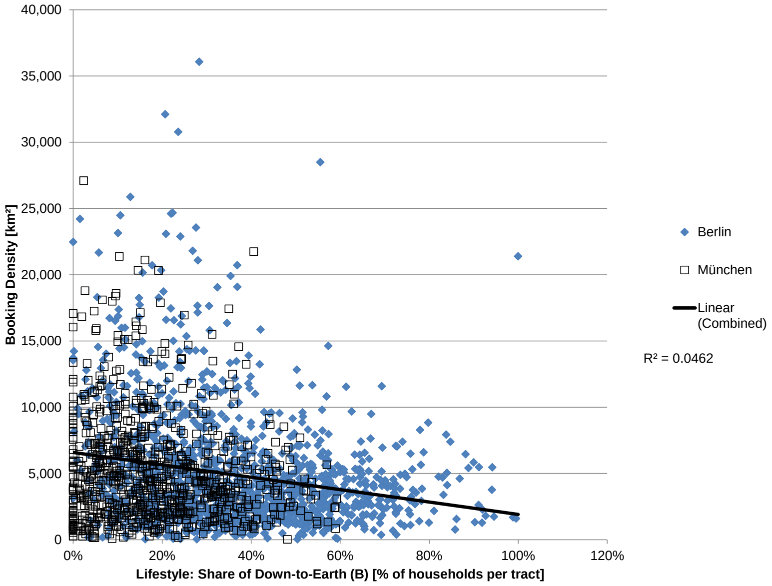

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
Used Car Ownership Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0089

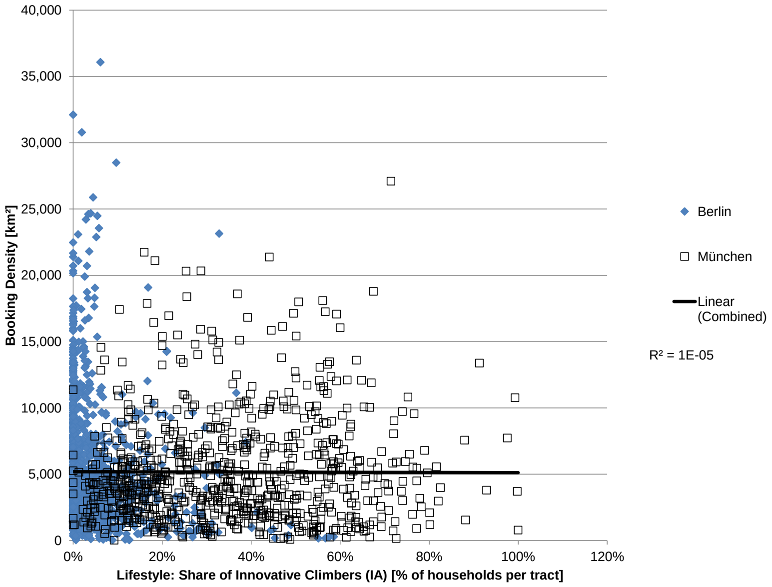

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
200
Environmental Affinity Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0139

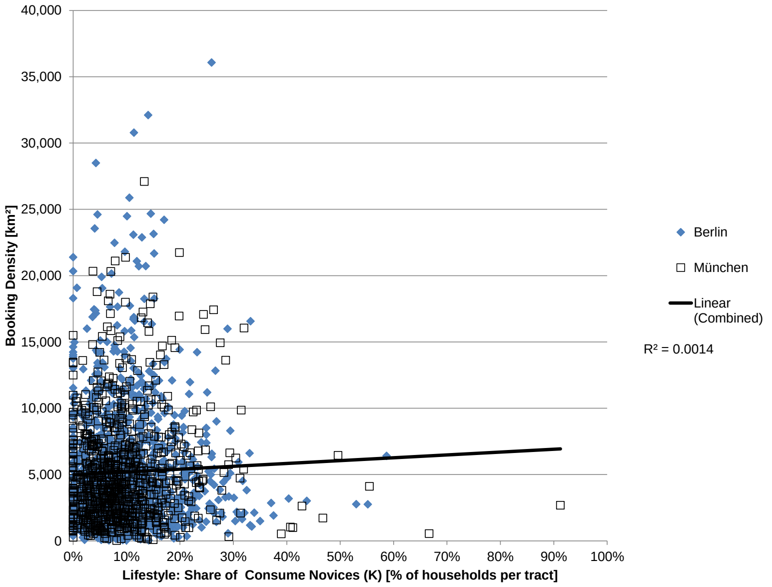

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
200
Natural Gas Vehicle Affinity Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0701

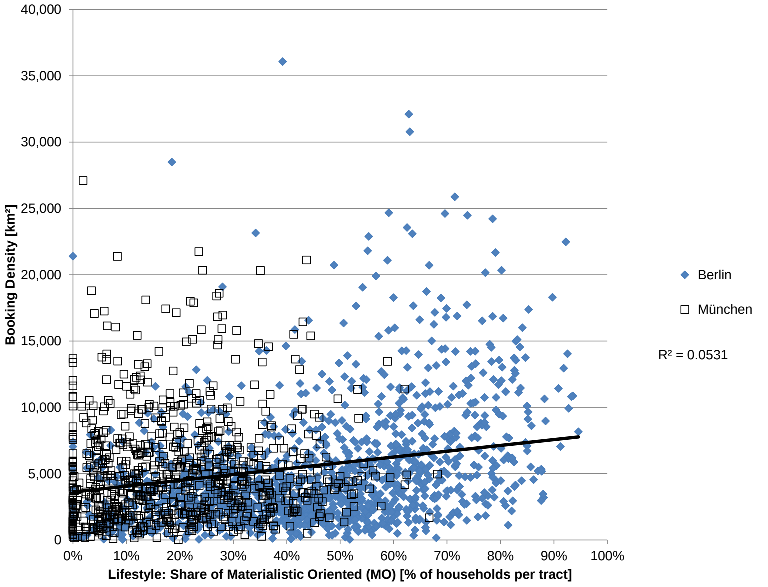

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
Factor Innovation Motivates Consumption as Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0214

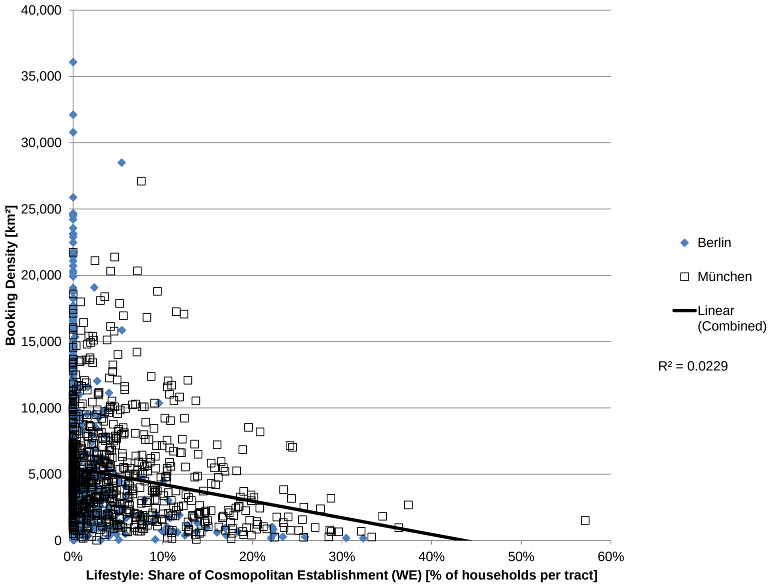

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
Lifestyle: Share of Active Middle (AM) [% of households per tract]
Berlin
München
Linear (Combined)
R² = 0.0016

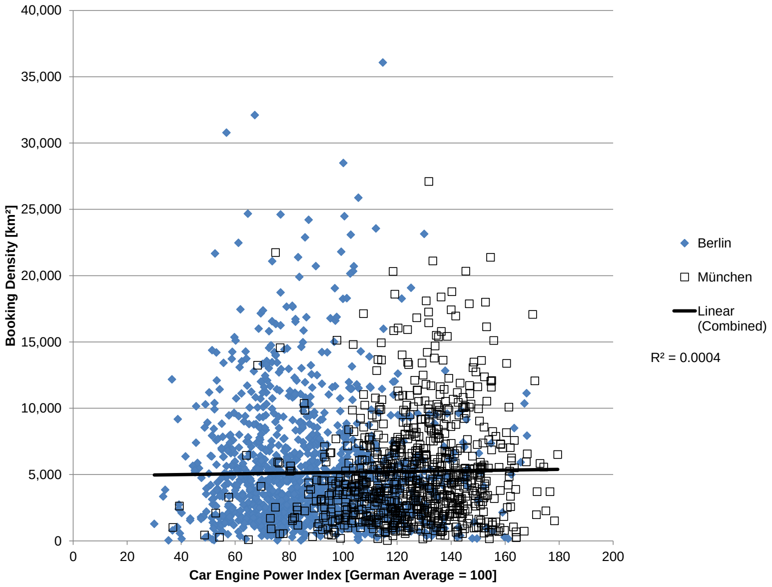

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Lifestyle: Share of Down-to-Earth (B) [% of households per tract]
Berlin
München
Linear (Combined)
R² = 0.0462

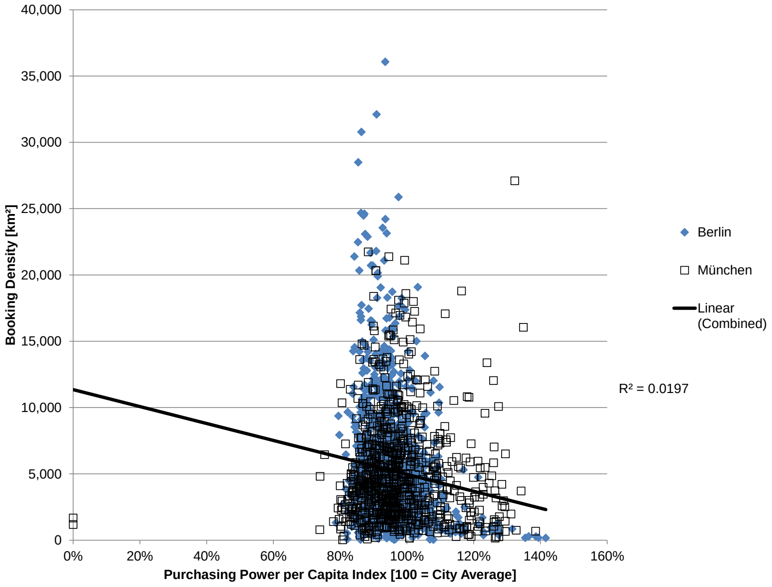

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Lifestyle: Share of Innovative Climbers (IA) [% of households per tract]
◆ Berlin
□ München
Linear (Combined)
R² = 1E-05

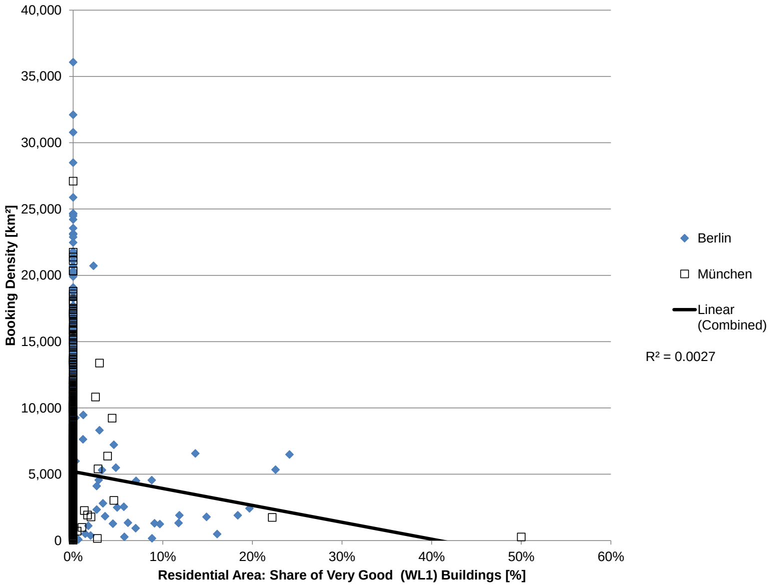

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Lifestyle: Share of Consume Novices (K) [% of households per tract]
◆ Berlin
□ München
Linear (Combined)
R² = 0.0014

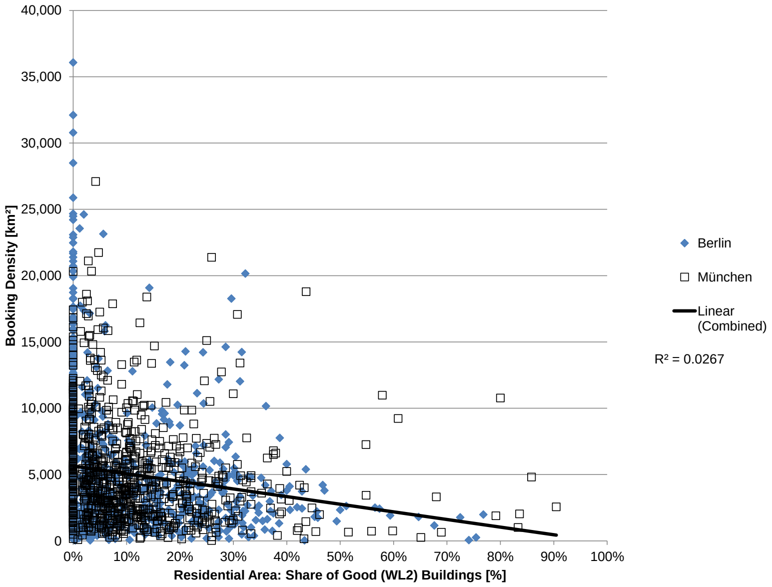

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Lifestyle: Share of Materialistic Oriented (MO) [% of households per tract]
◆ Berlin
□ München
R² = 0.0531

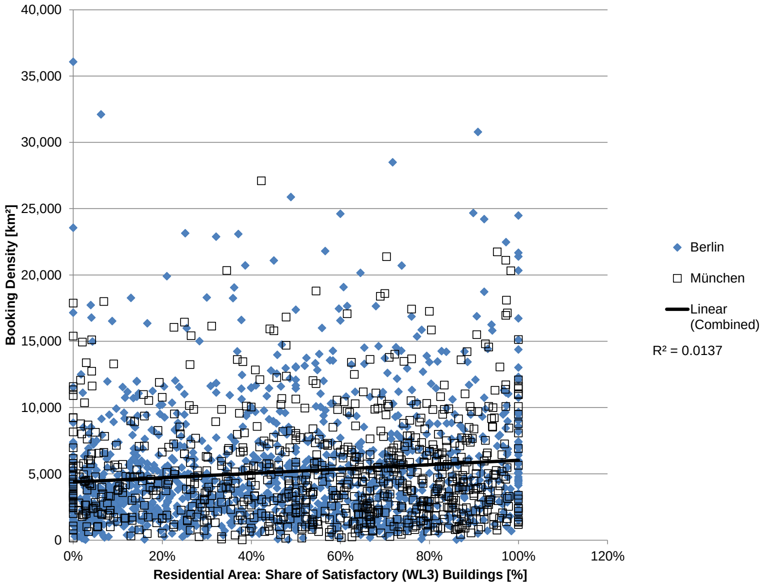

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
Lifestyle: Share of Cosmopolitan Establishment (WE) [% of households per tract]
Berlin
München
Linear (Combined)
R² = 0.0229

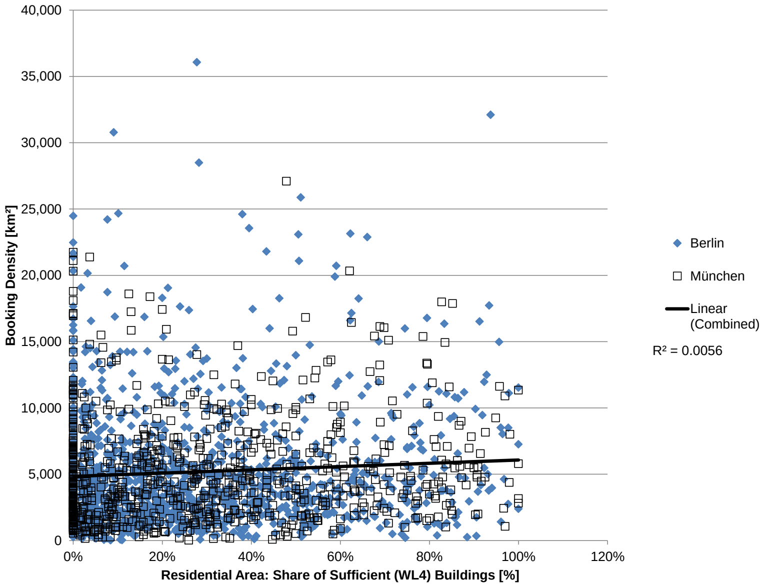

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
200
Car Engine Power Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0004

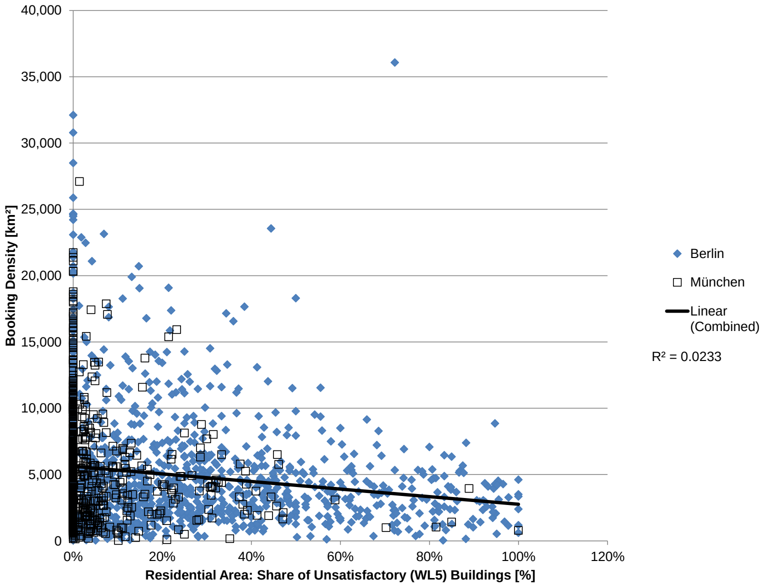

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
140%
160%
Purchasing Power per Capita Index [100 = City Average]
Berlin
München
Linear (Combined)
R² = 0.0197

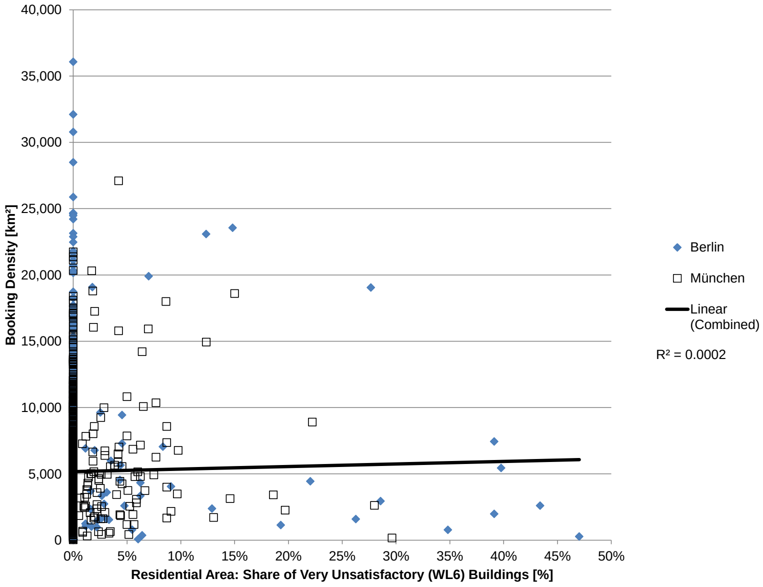

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
Residential Area: Share of Very Good (WL1) Buildings [%]
Berlin
München
Linear (Combined)
R² = 0.0027

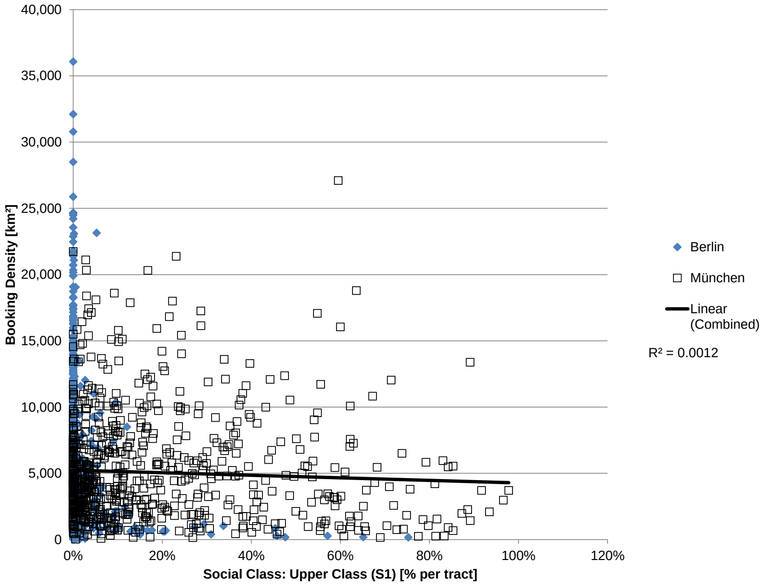

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Residential Area: Share of Good (WL2) Buildings [%]
Berlin
München
Linear (Combined)
R² = 0.0267

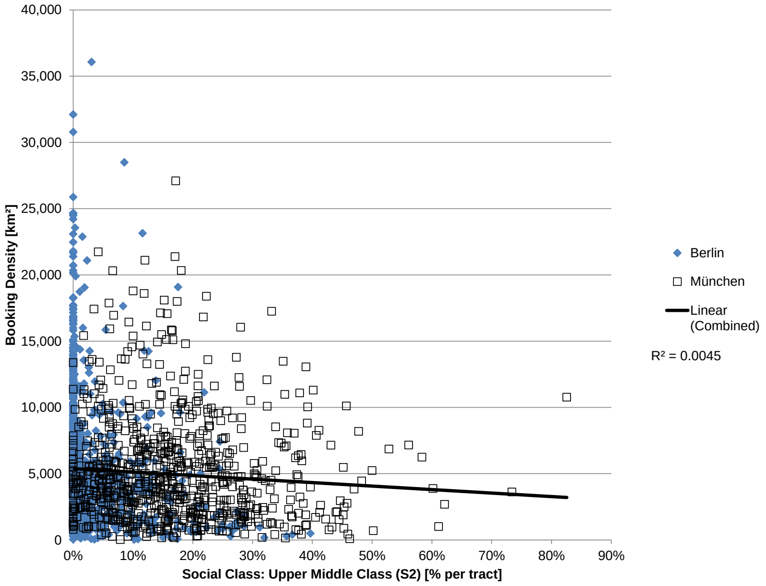

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Residential Area: Share of Satisfactory (WL3) Buildings [%]
Berlin
München
Linear (Combined)
R² = 0.0137

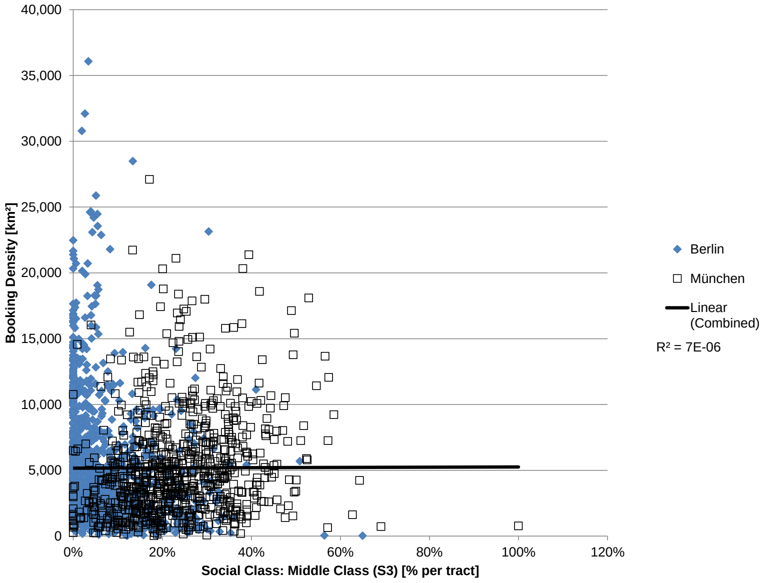

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Residential Area: Share of Sufficient (WL4) Buildings [%]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0056

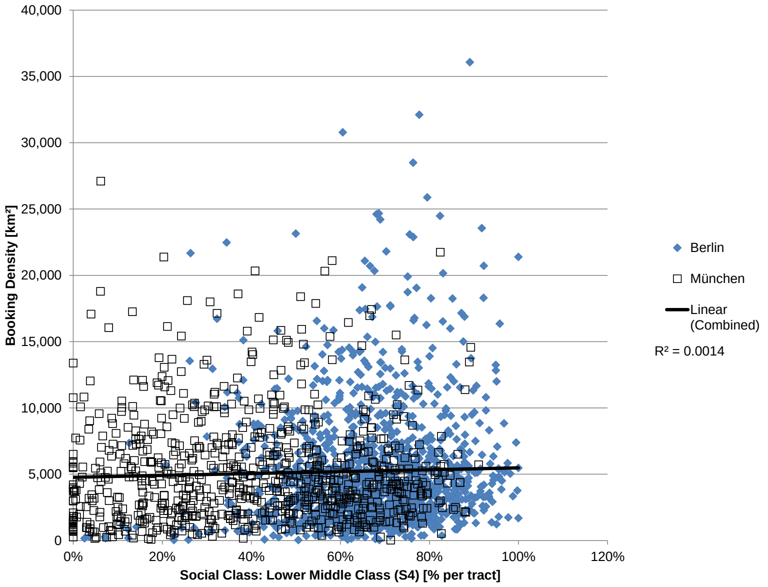

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Residential Area: Share of Unsatisfactory (WL5) Buildings [%]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0233

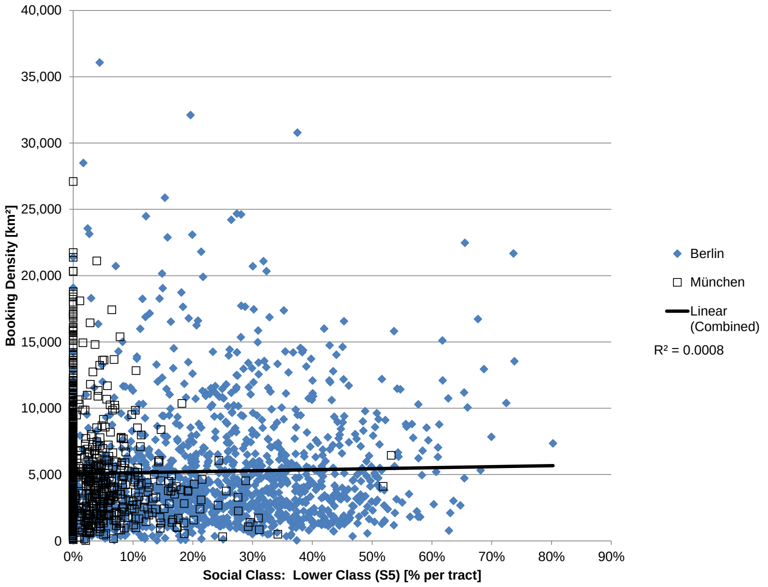

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
Residential Area: Share of Very Unsatisfactory (WL6) Buildings [%]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0002

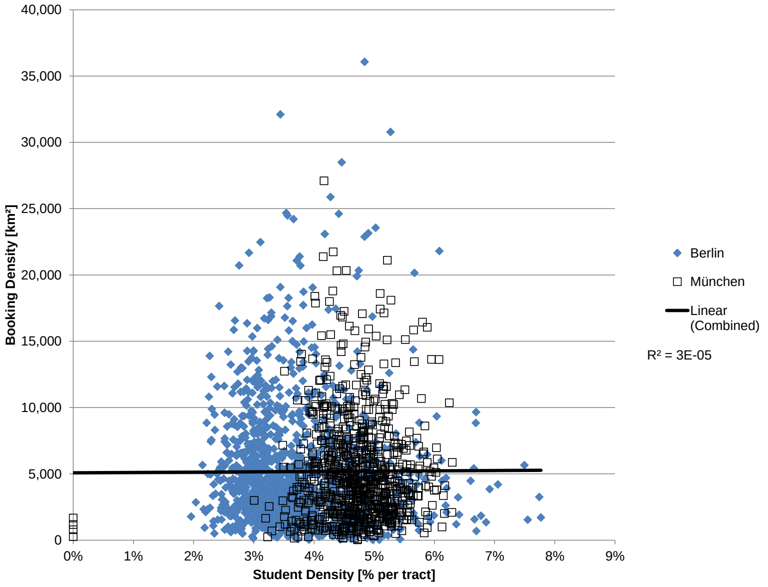

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Social Class: Upper Class (S1) [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0012

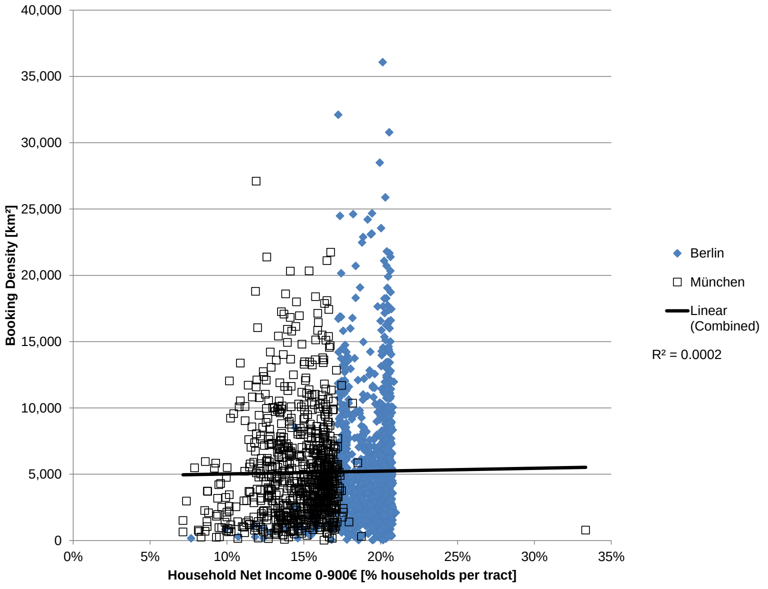

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
Social Class: Upper Middle Class (S2) [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0045

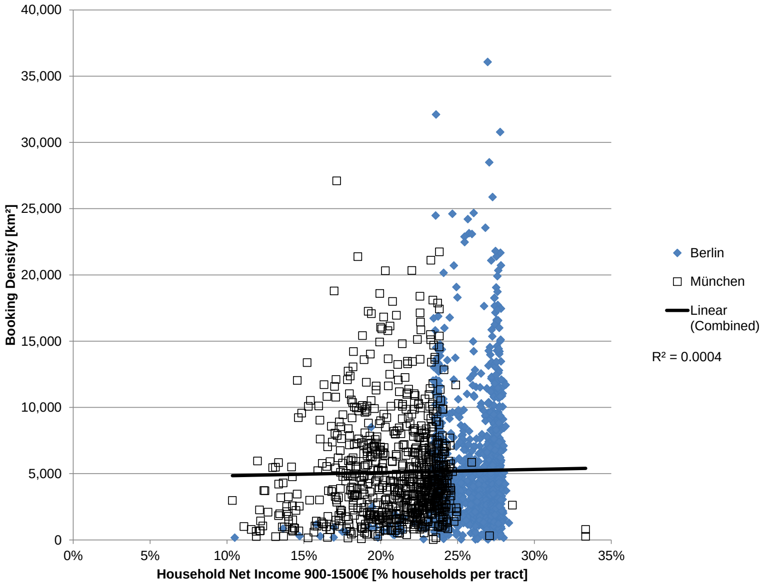

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Social Class: Middle Class (S3) [% per tract]
Berlin
München
Linear (Combined)
R² = 7E-06

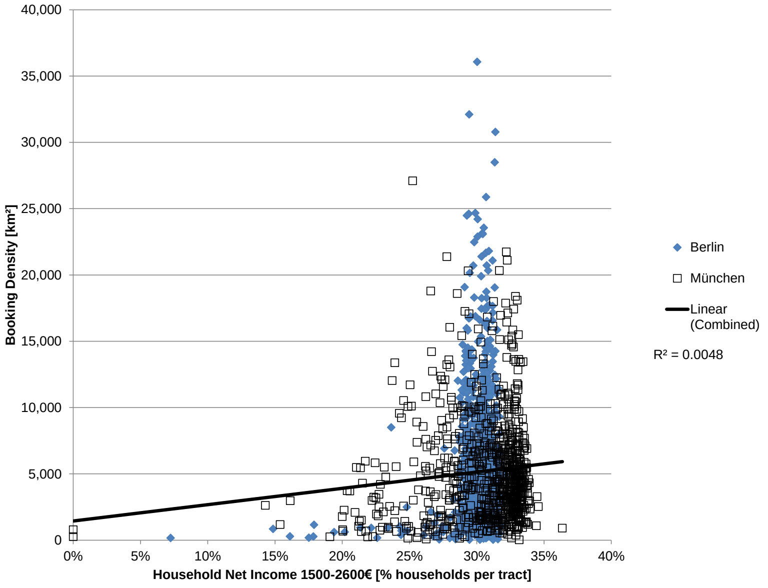

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
20%
40%
60%
80%
100%
120%
Social Class: Lower Middle Class (S4) [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0014

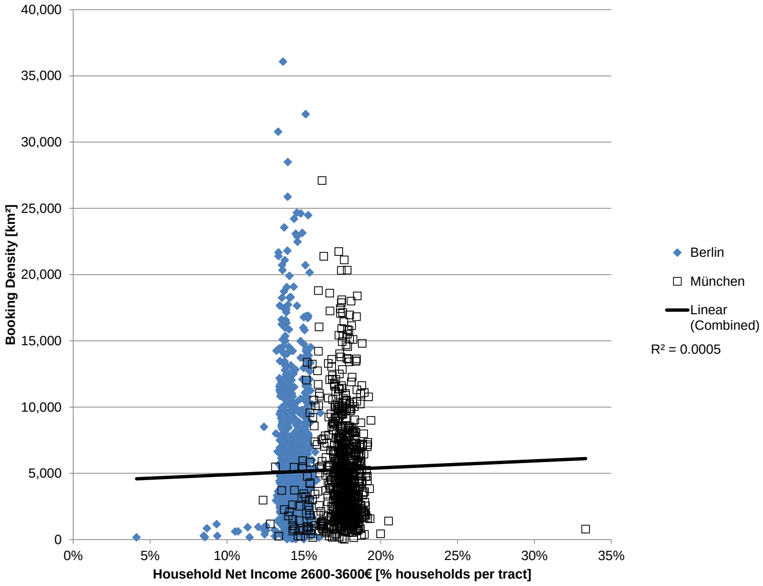

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
Social Class: Lower Class (S5) [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0008

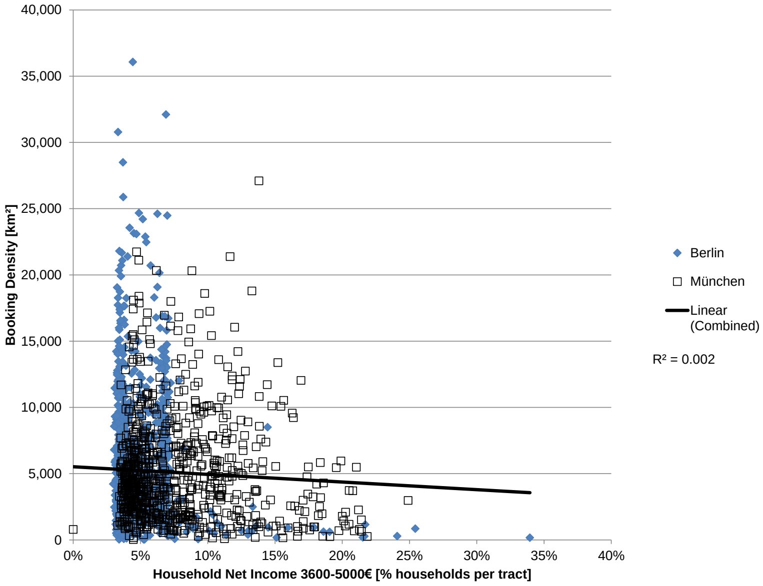

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
Student Density [% per tract]
Berlin
München
Linear (Combined)
R² = 3E-05

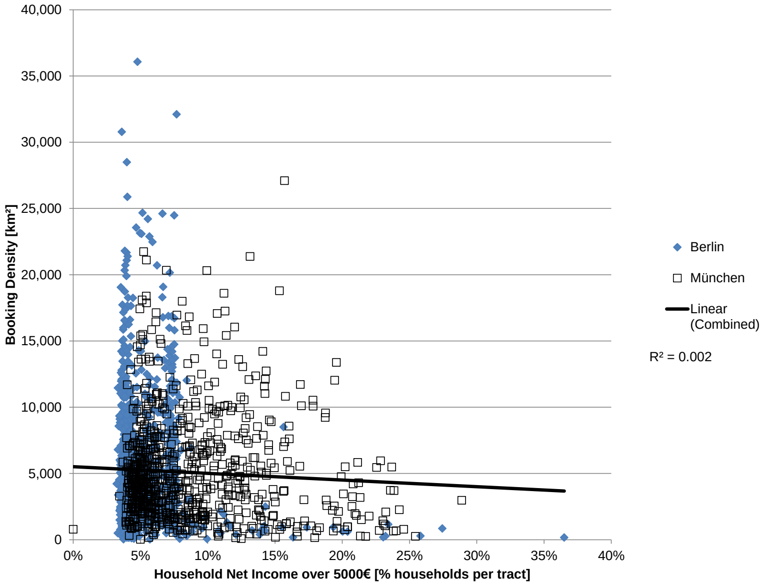

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
Household Net Income 0-900€ [% households per tract]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0002

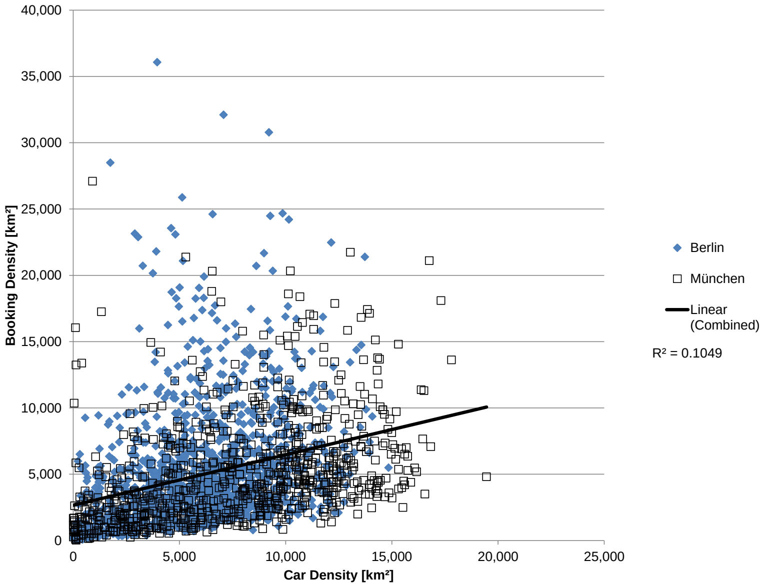

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
Household Net Income 900-1500€ [% households per tract]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0004

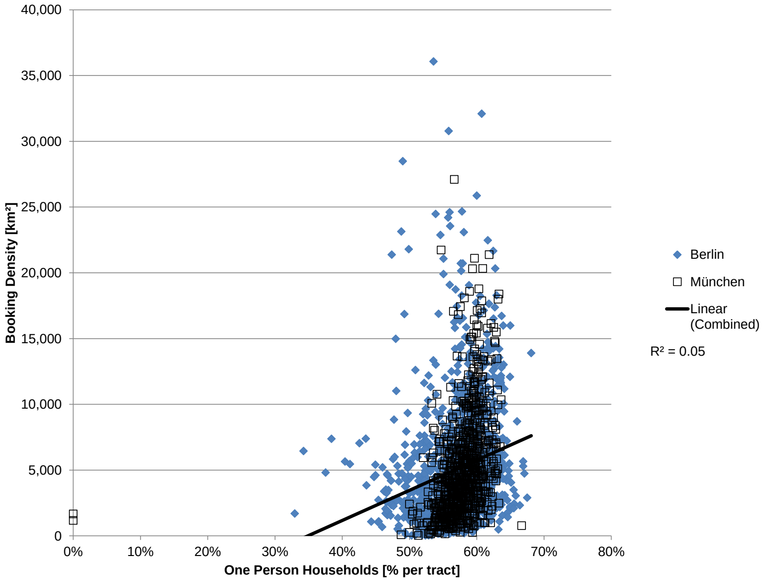

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
40%
Household Net Income 1500-2600€ [% households per tract]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0048

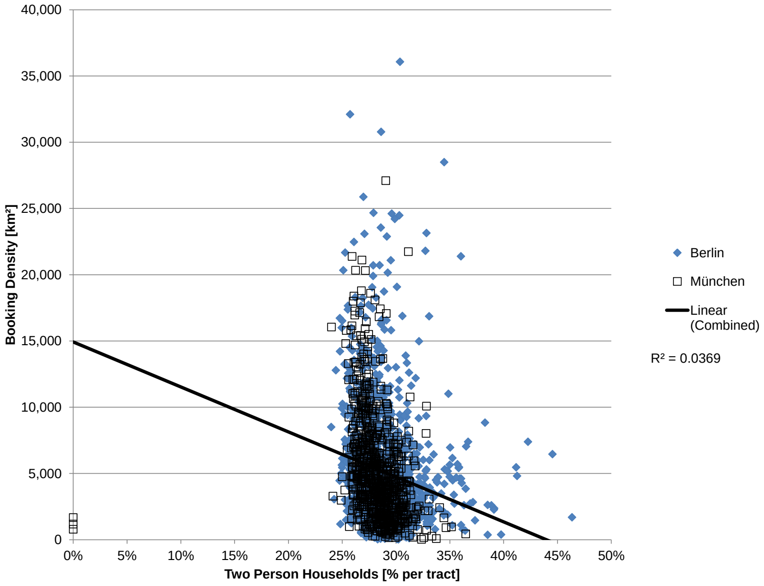

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
Household Net Income 2600-3600€ [% households per tract]
Berlin
München
Linear (Combined)
R² = 0.0005

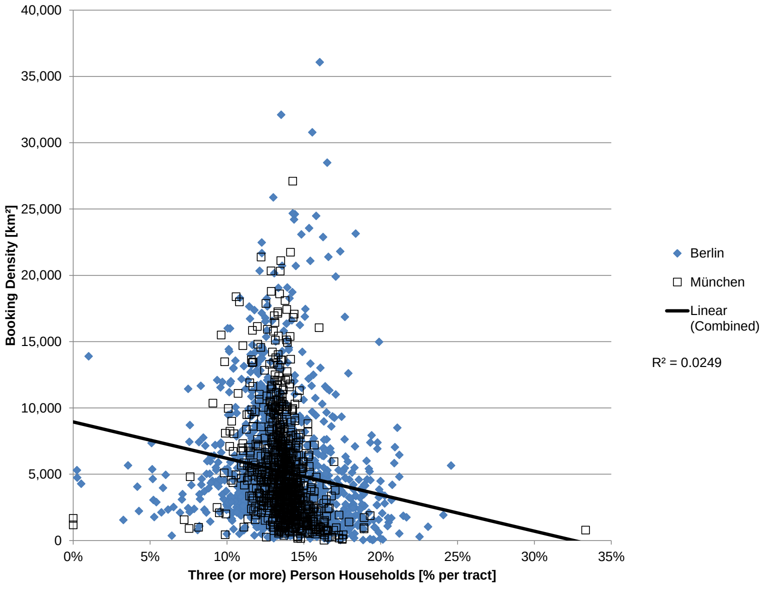

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
40%
Household Net Income 3600-5000€ [% households per tract]
Berlin
München
Linear (Combined)
R² = 0.002

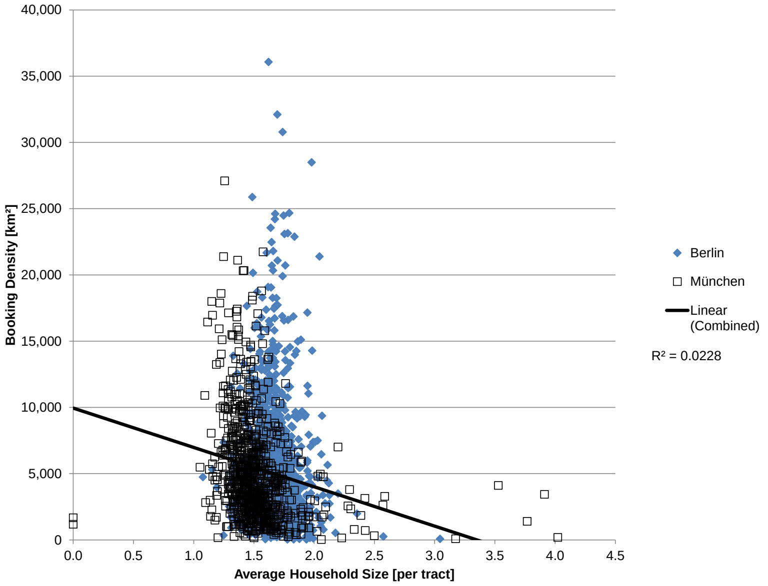

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
40%
Household Net Income over 5000€ [% households per tract]
Berlin
München
Linear (Combined)
R² = 0.002

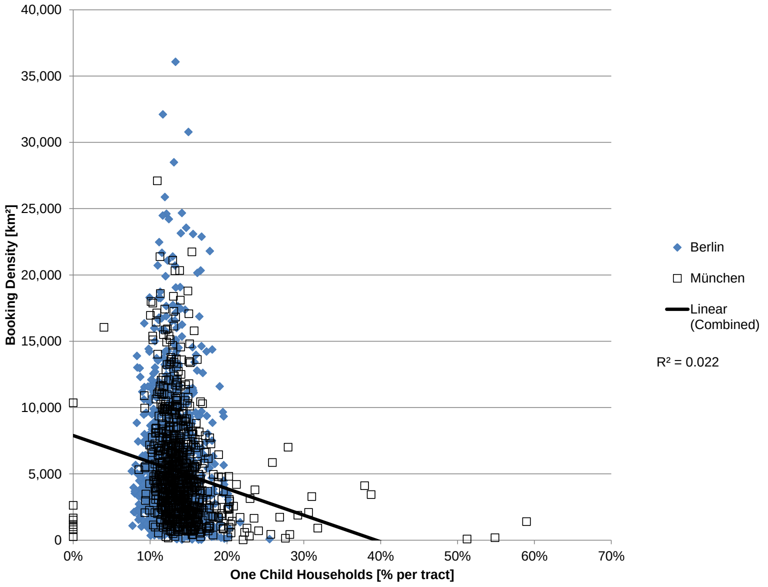

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
5,000
10,000
15,000
20,000
25,000
Car Density [km²]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.1049

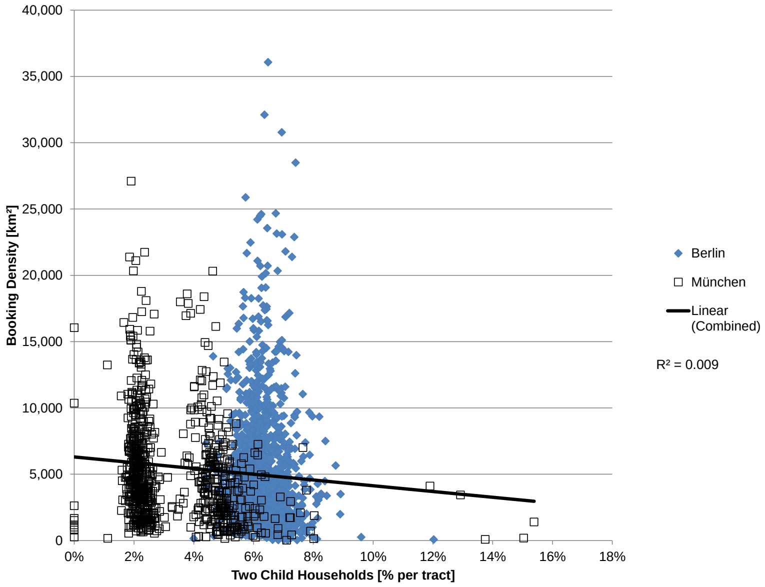

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
80%
One Person Households [% per tract]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.05

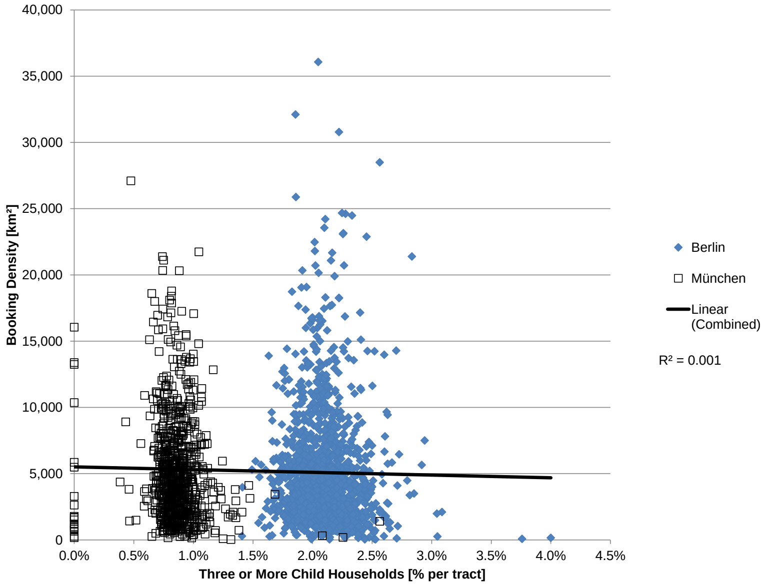

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
Two Person Households [% per tract]
◆ Berlin
☐ München
Linear (Combined)
R² = 0.0369

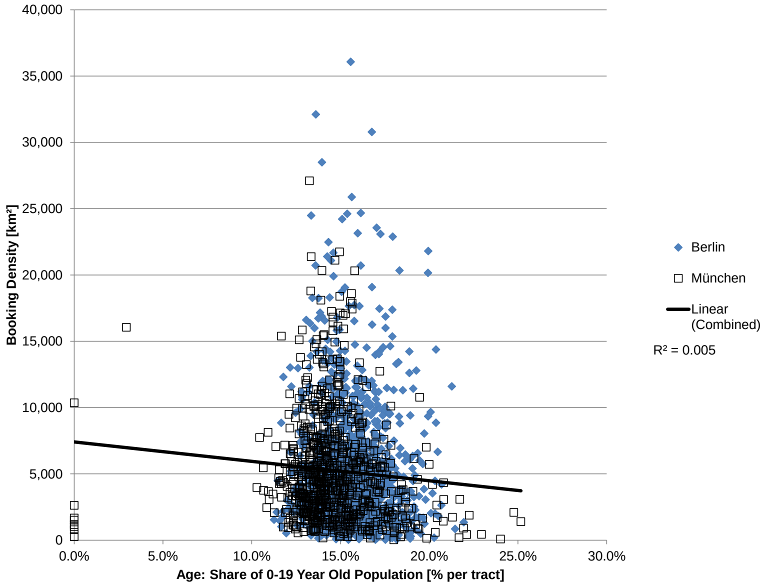

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
5%
10%
15%
20%
25%
30%
35%
Three (or more) Person Households [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0249

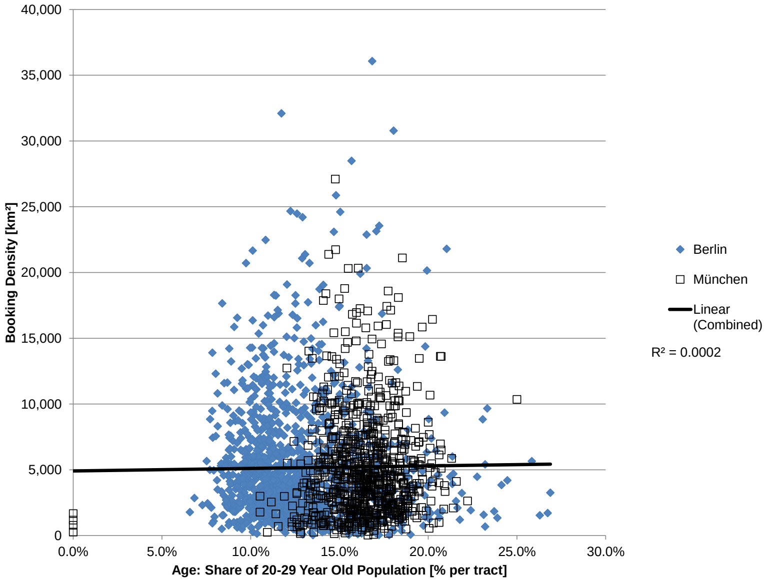

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Average Household Size [per tract]
Berlin
München
Linear (Combined)
R² = 0.0228

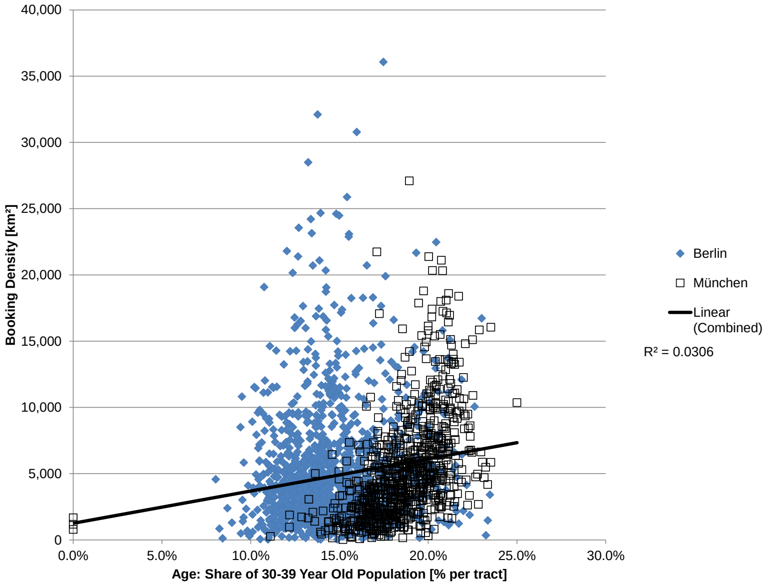

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
10%
20%
30%
40%
50%
60%
70%
One Child Households [% per tract]
Berlin
München
Linear (Combined)
R² = 0.022

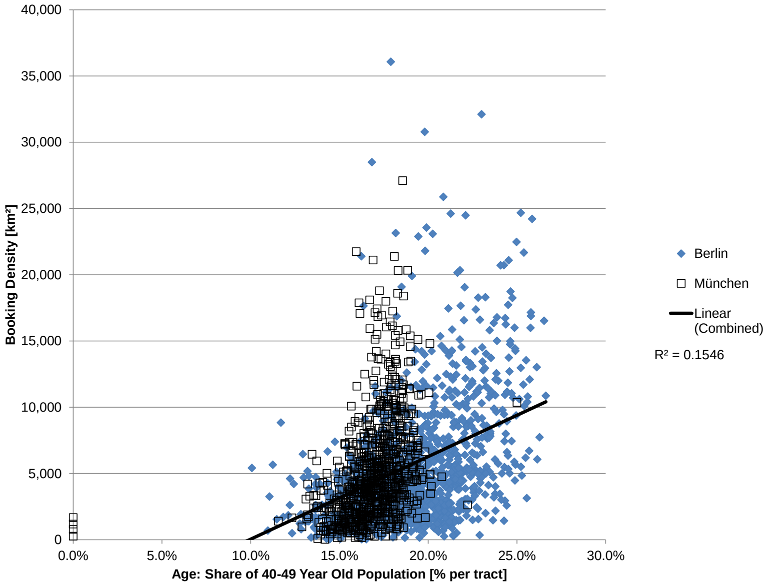

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
Two Child Households [% per tract]
Berlin
München
Linear (Combined)
R² = 0.009

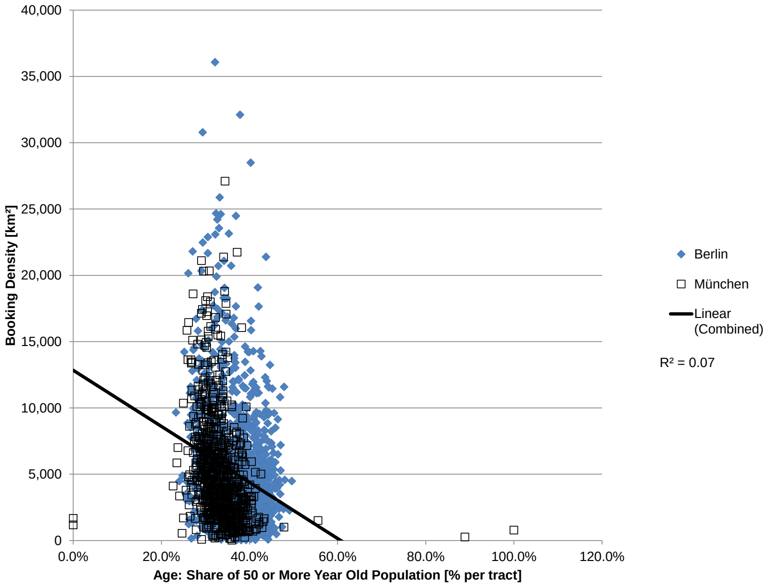

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0%
0.5%
1.0%
1.5%
2.0%
2.5%
3.0%
3.5%
4.0%
4.5%
Three or More Child Households [% per tract]
Berlin
München
Linear (Combined)
R² = 0.001

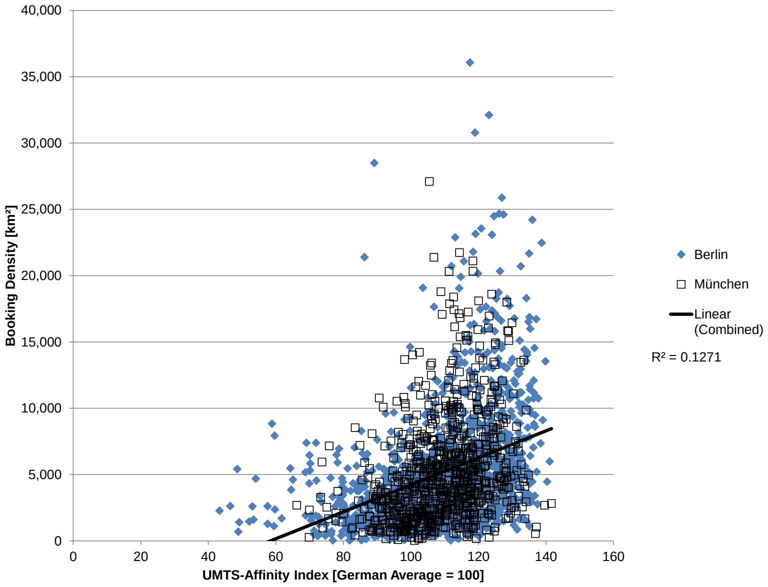

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%
Age: Share of 0-19 Year Old Population [% per tract]
Berlin
München
Linear (Combined)
R² = 0.005

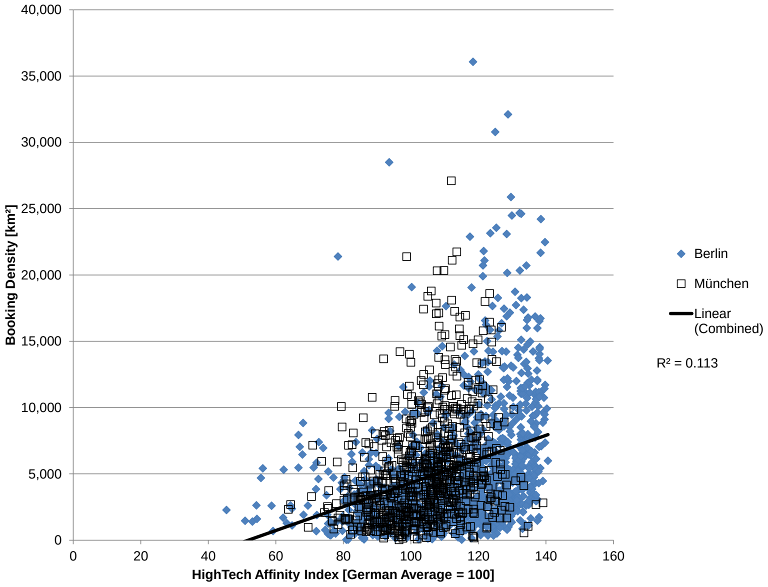

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%
Age: Share of 20-29 Year Old Population [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0002

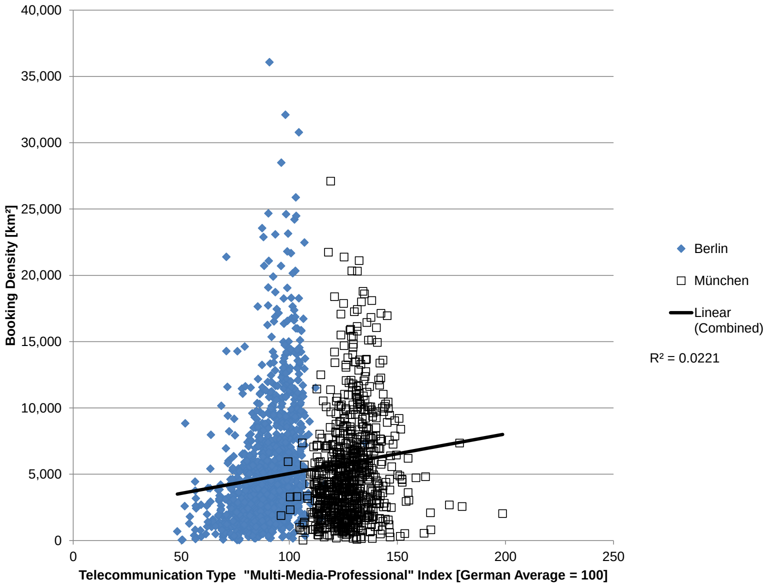

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%
Age: Share of 30-39 Year Old Population [% per tract]
Berlin
München
Linear (Combined)
R² = 0.0306

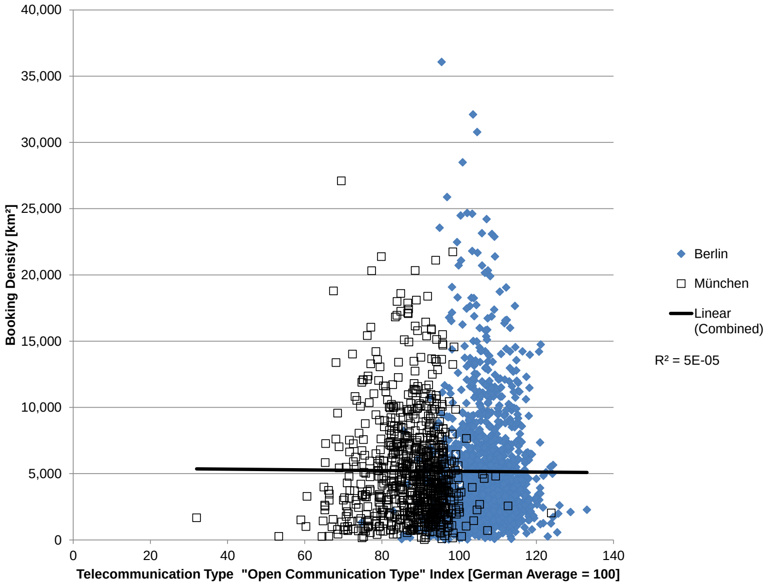

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%
Age: Share of 40-49 Year Old Population [% per tract]
Berlin
München
Linear (Combined)
R² = 0.1546

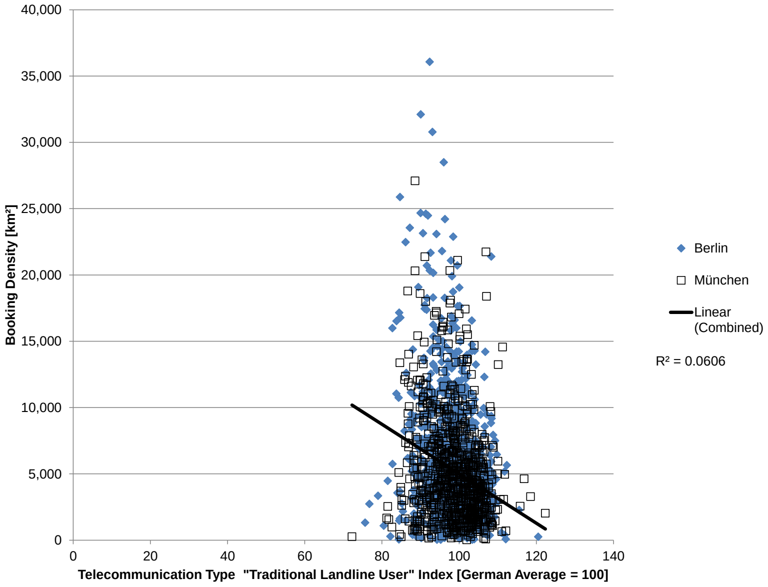

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%
120.0%
Age: Share of 50 or More Year Old Population [% per tract]
◆ Berlin
□ München
Linear (Combined)
R² = 0.07

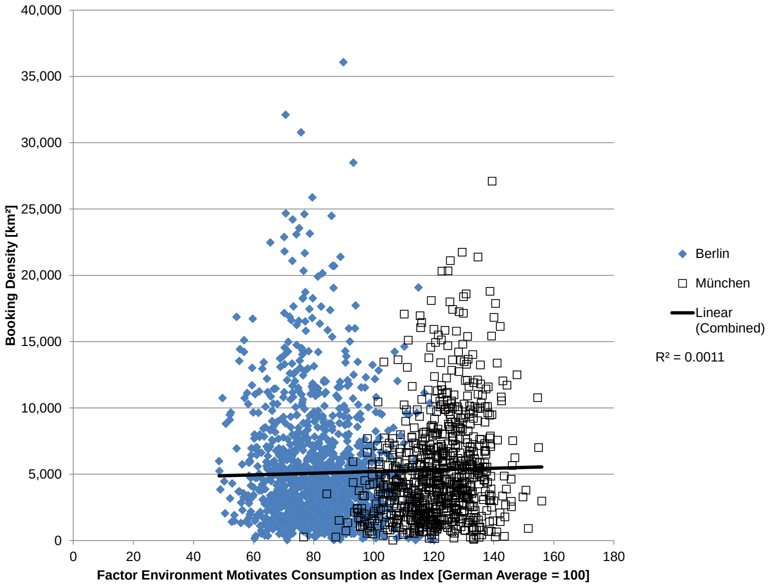

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
UMTS-Affinity Index [German Average = 100]
◆ Berlin
□ München
Linear (Combined)
R² = 0.1271

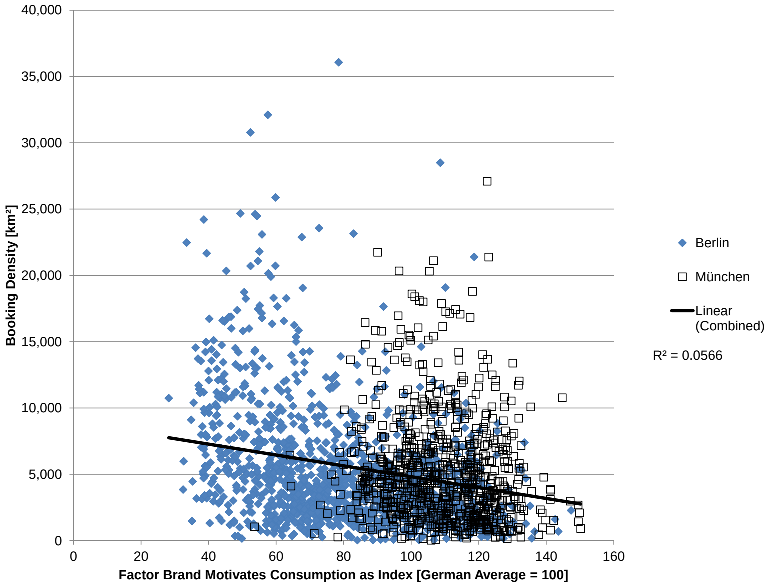

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
HighTech Affinity Index [German Average = 100]
◆ Berlin
□ München
Linear (Combined)
R² = 0.113

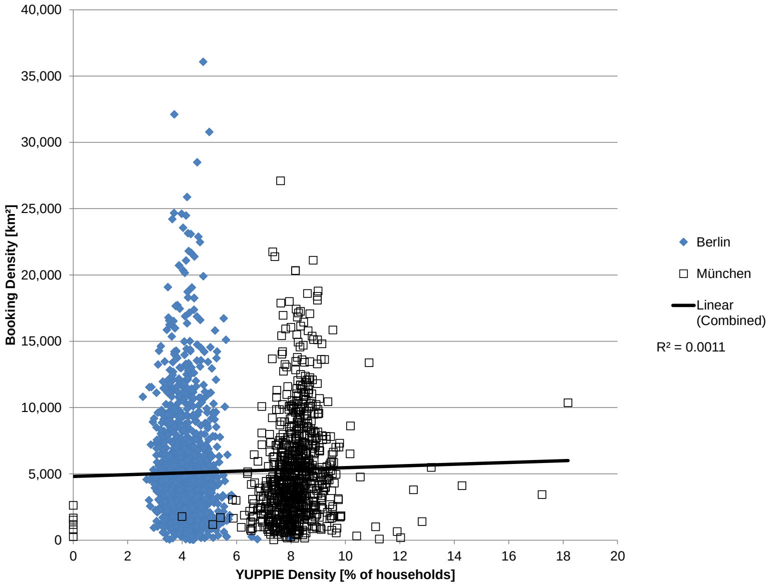

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
50
100
150
200
250
Telecommunication Type "Multi-Media-Professional" Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0221

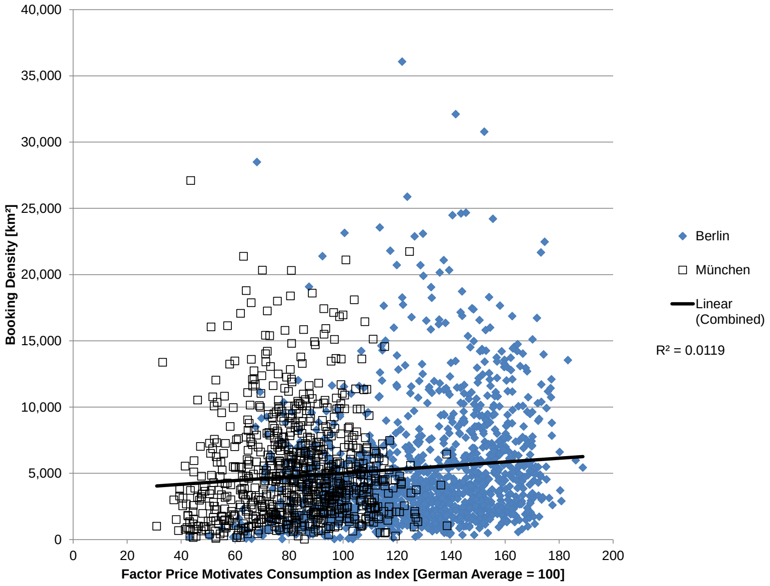

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
Telecommunication Type "Open Communication Type" Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 5E-05


40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
Telecommunication Type "Traditional Landline User" Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0606


Booking Density [km²]
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
20
40
60
80
100
120
140
160
180
Factor Environment Motivates Consumption as Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0011

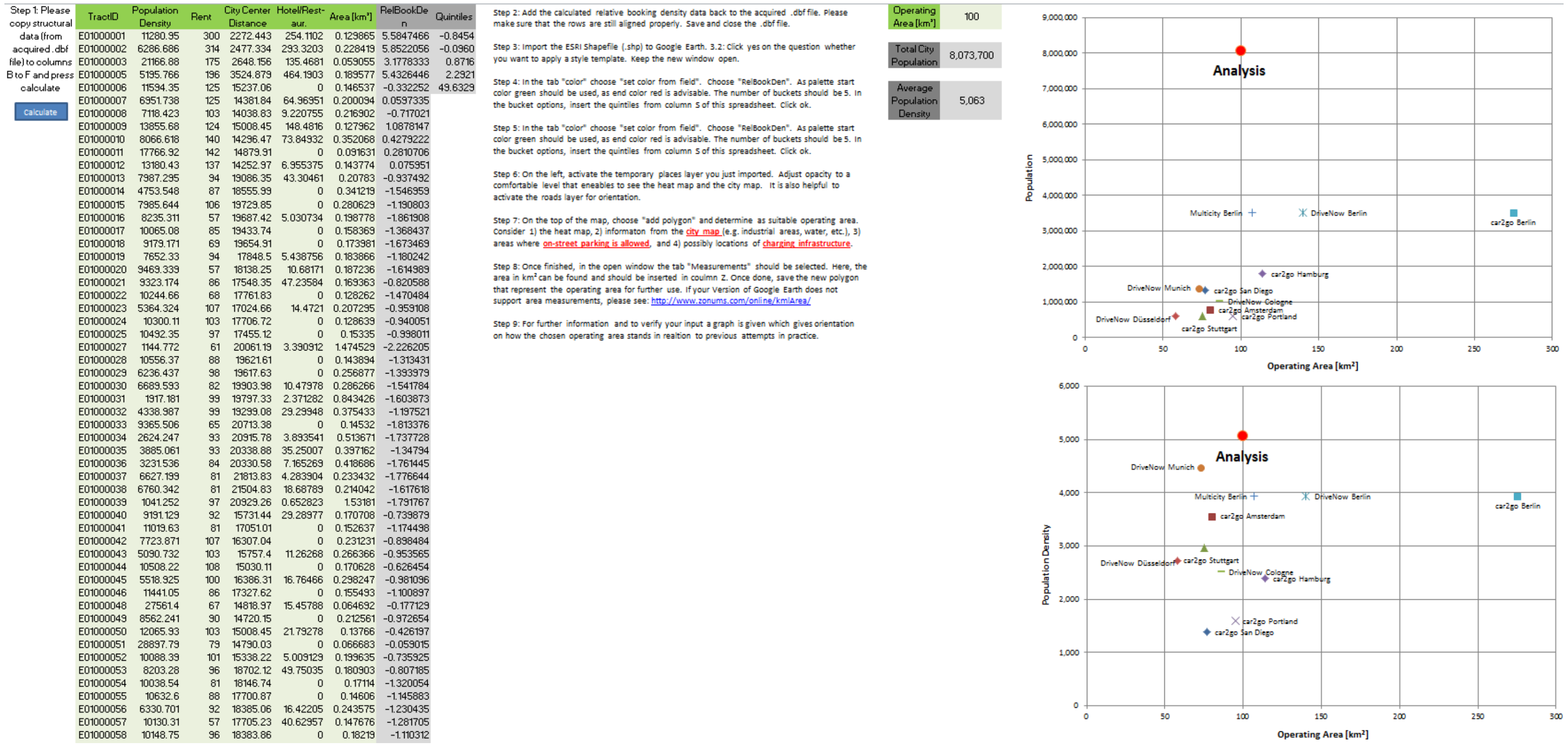

Booking Density [km²]
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
20
40
60
80
100
120
140
160
Factor Brand Motivates Consumption as Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0566


Booking Density [km²]
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
2
4
6
8
10
12
14
16
18
20
YUPPIE Density [% of households]
Berlin
München
Linear (Combined)
R² = 0.0011


40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Booking Density [km²]
0
20
40
60
80
100
120
140
160
180
200
Factor Price Motivates Consumption as Index [German Average = 100]
Berlin
München
Linear (Combined)
R² = 0.0119

Appendix G

Screenshots of the Decision Support System



Step 1: Please copy structural data (from acquired .dbf file) to columns B to F and press calculate

TractID	Population Density	Rent	City Center Distance	Hotel/Rest-aur.	Area [km²]	RelBookDen	Quintiles
E01000001	11280.95	300	2272.443	254.1102	0.129865	5.5847466	-0.8454
E01000002	6286.686	314	2477.334	293.3203	0.228419	5.8522056	-0.0960
E01000003	21166.88	175	2648.156	135.4681	0.059055	3.1778333	0.8716
E01000005	5195.766	196	3524.879	464.1903	0.189577	5.4326446	2.2921
E01000006	11594.35	125	15237.06	0	0.146537	-0.332252	49.6329
E01000007	6951.738	125	14381.84	64.96951	0.200094	0.0597335	
E01000008	7118.423	103	14038.83	9.220755	0.216902	-0.717021	
E01000009	13855.68	124	15008.45	148.4816	0.127962	1.0878147	
E01000010	8066.618	140	14296.47	73.84932	0.352068	0.4279222	
E01000011	17766.92	142	14879.91	0	0.091631	0.2810706	
E01000012	13180.43	137	14252.97	6.955375	0.143774	0.075951	
E01000013	7987.295	94	19086.35	43.30461	0.20783	-0.937492	
E01000014	4753.548	87	18555.99	0	0.341219	-1.546959	
E01000015	7985.644	106	19729.85	0	0.280629	-1.190803	
E01000016	8235.311	57	19687.42	5.030734	0.198778	-1.861908	
E01000017	10065.08	85	19433.74	0	0.158369	-1.368437	
E01000018	9179.171	69	19654.91	0	0.173981	-1.673469	
E01000019	7652.33	94	17848.5	5.438756	0.183866	-1.180242	
E01000020	9469.339	57	18138.25	10.68171	0.187236	-1.614989	
E01000021	9323.174	86	17548.35	47.23584	0.169363	-0.820588	
E01000022	10244.66	68	17761.83	0	0.128262	-1.470484	
E01000023	5364.324	107	17024.66	14.4721	0.207295	-0.959108	
E01000024	10300.11	103	17706.72	0	0.128639	-0.940051	
E01000025	10492.35	97	17455.12	0	0.15335	-0.998011	
E01000027	1144.772	61	20061.19	3.390912	1.474529	-2.226205	
E01000028	10556.37	88	19621.61	0	0.143894	-1.313431	
E01000029	6236.437	98	19617.63	0	0.256877	-1.393979	
E01000030	6689.593	82	19903.98	10.47978	0.286266	-1.541784	
E01000031	1917.181	99	19797.33	2.371282	0.843426	-1.603873	
E01000032	4338.987	99	19299.08	29.29948	0.375433	-1.197521	
E01000033	9365.506	65	20713.38	0	0.14532	-1.813376	
E01000034	2624.247	93	20915.78	3.893541	0.513671	-1.737728	
E01000035	3885.061	93	20338.88	35.25007	0.397162	-1.34794	
E01000036	3231.536	84	20330.58	7.165269	0.418686	-1.761445	
E01000037	6627.199	81	21813.83	4.283904	0.233432	-1.776644	
E01000038	6760.342	81	21504.83	18.68789	0.214042	-1.617618	
E01000039	1041.252	97	20929.26	0.652823	1.53181	-1.791767	
E01000040	9191.129	92	15731.44	29.28977	0.170708	-0.739879	
E01000041	11019.63	81	17051.01	0	0.152637	-1.174498	
E01000042	7723.871	107	16307.04	0	0.231231	-0.898484	
E01000043	5090.732	103	15757.4	11.26268	0.266366	-0.953565	
E01000044	10508.22	108	15030.11	0	0.170628	-0.626454	
E01000045	5518.925	100	16386.31	16.76466	0.298247	-0.981096	
E01000046	11441.05	86	17327.62	0	0.155493	-1.100897	
E01000048	27561.4	67	14818.97	15.45788	0.064692	-0.177129	
E01000049	8562.241	90	14720.15	0	0.212561	-0.972654	
E01000050	12065.93	103	15008.45	21.79278	0.13766	-0.426197	
E01000051	28897.79	79	14790.03	0	0.066683	-0.059015	
E01000052	10088.39	101	15338.22	5.009129	0.199635	-0.735925	
E01000053	8203.28	96	18702.12	49.75035	0.180903	-0.807185	
E01000054	10038.54	81	18146.74	0	0.17114	-1.320054	
E01000055	10632.6	88	17700.87	0	0.14606	-1.145883	
E01000056	6330.701	92	18385.06	16.42205	0.243575	-1.230435	
E01000057	10130.31	57	17705.23	40.62957	0.147676	-1.281705	
E01000058	10148.75	96	18383.86	0	0.18219	-1.110312	

Step 2: Add the calculated relative booking density data back to the acquired .dbf file. Please make sure that the rows are still aligned properly. Save and close the .dbf file.

Step 3: Import the ESRI Shapefile (.shp) to Google Earth. 3.2: Click yes on the question whether you want to apply a style template. Keep the new window open.

Step 4: In the tab "color" choose "set color from field". Choose "RelBookDen". As palette start color green should be used, as end color red is advisable. The number of buckets should be 5. In the bucket options, insert the quintiles from column 5 of this spreadsheet. Click ok.

Step 5: In the tab "color" choose "set color from field". Choose "RelBookDen". As palette start color green should be used, as end color red is advisable. The number of buckets should be 5. In the bucket options, insert the quintiles from column 5 of this spreadsheet. Click ok.

Step 6: On the left, activate the temporary places layer you just imported. Adjust opacity to a comfortable level that eneables to see the heat map and the city map. It is also helpful to activate the roads layer for orientation.

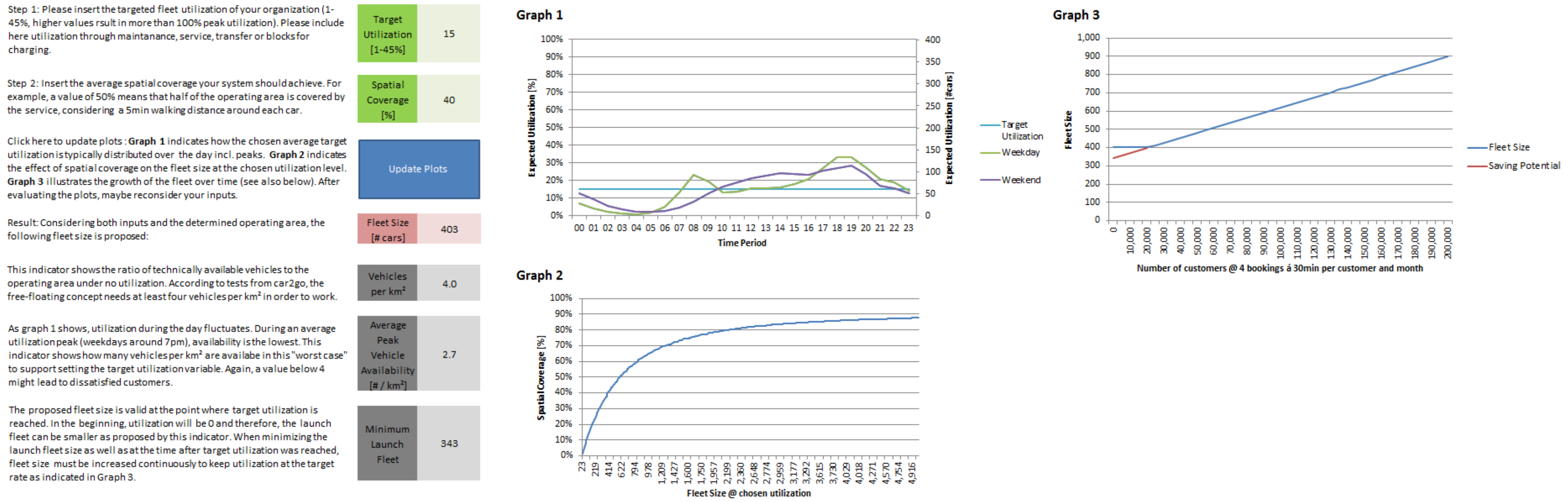
Step 7: On the top of the map, choose "add polygon" and determine as suitable operating area. Consider 1) the heat map, 2) informaton from the city map (e.g. industrial areas, water, etc.), 3) areas where on-street parking is allowed, and 4) possibly locations of charging infrastructure.

Step 8: Once finished, in the open window the tab "Measurements" should be selected. Here, the area in km² can be found and should be inserted in coulmn Z. Once done, save the new polygon that represent the operating area for further use. If your Version of Google Earth does not support area measurements, please see: http://www.zonums.com/online/kmlArea/

Step 9: For further information and to verify your input a graph is given which gives orientation on how the chosen operating area stands in realtion to previous attempts in practice.

Operating Area [km²]	100
Total City Population	8,073,700
Average Population Density	5,063

Figure G.1: Operating Area Module



Step 1: Please insert the targeted fleet utilization of your organization (1-45%, higher values rsult in more than 100% peak utilization). Please include here utilization through maintanance, service, transfer or blocks for charging.	Target Utilization [1-45%]	15
Step 2: Insert the average spatial coverage your system should achieve. For example, a value of 50% means that half of the operating area is covered by the service, considering a 5min walking distance around each car.	Spatial Coverage [%]	40
Click here to update plots : **Graph 1** indicates how the chosen average target utilization is typically distributed over the day incl. peaks. **Graph 2** indicates the effect of spatial coverage on the fleet size at the chosen utilization level. **Graph 3** illustrates the growth of the fleet over time (see also below). After evaluating the plots, maybe reconsider your inputs.	Update Plots	
Result: Considering both inputs and the determined operating area, the following fleet size is proposed:	Fleet Size [# cars]	403
This indicator shows the ratio of technically available vehicles to the operating area under no utilization. According to tests from car2go, the free-floating concept needs at least four vehicles per km² in order to work.	Vehicles per km²	4.0
As graph 1 shows, utilization during the day fluctuates. During an average utilization peak (weekdays around 7pm), availability is the lowest. This indicator shows how many vehicles per km² are availabe in this "worst case" to support setting the target utilization variable. Again, a value below 4 might lead to dissatisfied customers.	Average Peak Vehicle Availability [# / km²]	2.7
The proposed fleet size is valid at the point where target utilization is reached. In the beginning, utilization will be 0 and therefore, the launch fleet can be smaller as proposed by this indicator. When minimizing the launch fleet size as well as at the time after target utilization was reached, fleet size must be increased continuously to keep utilization at the target rate as indicated in Graph 3.	Minimum Launch Fleet	343

Figure G.2: Fleet Size Module

Step 1: Please insert the number of charging stations in the determined operating area, that can be used for your vehicles.

Number of Charging Stations [#]: 1600

Step 2: Please consider the spatial distribution and technology of chargers. Charging stations should be equally distributed within the operating area and hotspots should be equpped with fast chargers. ideally, the determination of the operating area already considered this fact.

Step 3: Considering the charging station density, a central (value of <3) or a decentralized (>=3) charging concept is proposed. However, if the value lies slightly above or below this border the proposition should be questioned. To explore sensitivities, the charging station density is given for your information as well as the graph on the right provides orientation.

Proposed Charging Concept: Decentralized

Charging Station Density [#/km²]: 16

Step 4: If sensitivity analysis or future developments clash with the recommendation, it is possible to overwrite the recommendation and choose a charging concept manually. If there is agreement with the proposition, please leave the field blank. For negotiations, please find the number of missing stations to employ decentralized charging on the right.

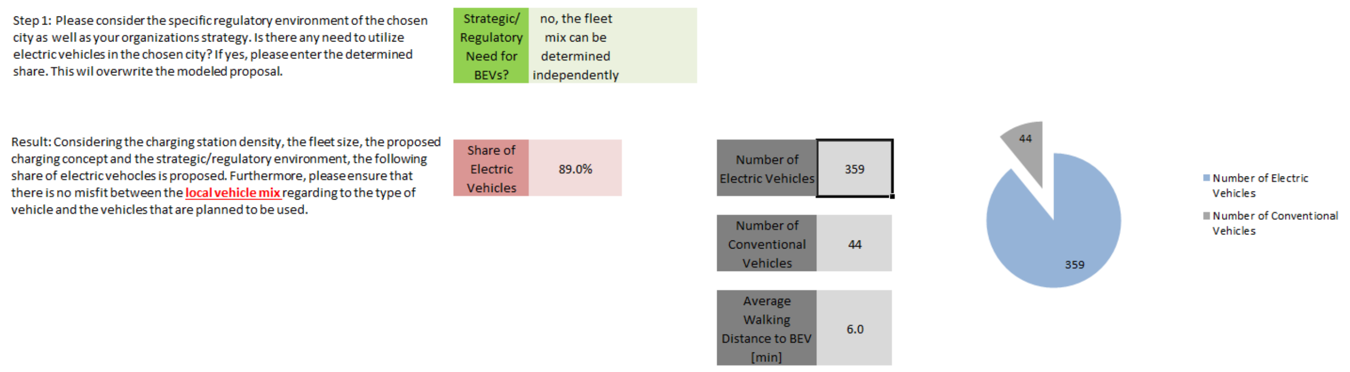
Charging Concept Overwrite Mode:

Missing Stations to Decentralized Charging: 0

Result: Considering the charging station density and potential manual inputs, the following charging concept is determined.

Charging Concept: Decentralized

Figure G.3: Charging Concept Module



Step 1: Please consider the specific regulatory environment of the chosen city as well as your organizations strategy. Is there any need to utilize electric vehicles in the chosen city? If yes, please enter the determined share. This wil overwrite the modeled proposal.

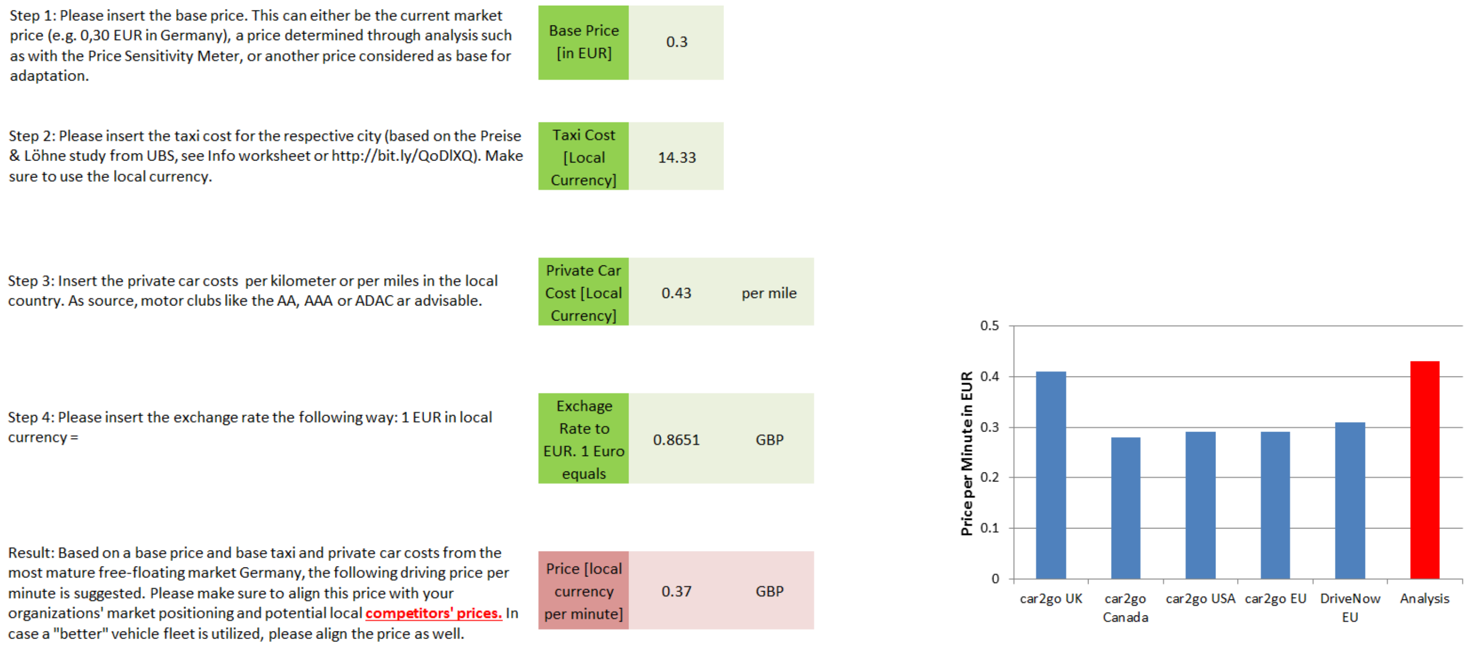
Strategic/ Regulatory Need for BEVs?	no, the fleet mix can be determined independently

Result: Considering the charging station density, the fleet size, the proposed charging concept and the strategic/regulatory environment, the following share of electric vehocles is proposed. Furthermore, please ensure that there is no misfit between the local vehicle mix regarding to the type of vehicle and the vehicles that are planned to be used.

Share of Electric Vehicles	89.0%

Number of Electric Vehicles	359
Number of Conventional Vehicles	44
Average Walking Distance to BEV [min]	6.0

Figure G.4: Fleet Mix Module



Step 1: Please insert the base price. This can either be the current market price (e.g. 0,30 EUR in Germany), a price determined through analysis such as with the Price Sensitivity Meter, or another price considered as base for adaptation.

Base Price [in EUR]	0.3	

Step 2: Please insert the taxi cost for the respective city (based on the Preise & Löhne study from UBS, see Info worksheet or http://bit.ly/QoDlXQ). Make sure to use the local currency.

Taxi Cost [Local Currency]	14.33	

Step 3: Insert the private car costs per kilometer or per miles in the local country. As source, motor clubs like the AA, AAA or ADAC ar advisable.

Private Car Cost [Local Currency]	0.43	per mile

Step 4: Please insert the exchange rate the following way: 1 EUR in local currency =

Exchage Rate to EUR. 1 Euro equals	0.8651	GBP

Result: Based on a base price and base taxi and private car costs from the most mature free-floating market Germany, the following driving price per minute is suggested. Please make sure to align this price with your organizations' market positioning and potential local **competitors' prices.** In case a "better" vehicle fleet is utilized, please align the price as well.

Price [local currency per minute]	0.37	GBP

Figure G.5: Price Module