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MASTER THESIS

INEFFICIENCIES OF BUSINESS INTERNAL CARSHARING : PROPOSING REVENUE MANAGEMENT CONCEPTS TO ACHIEVE FINANCIAL AND ENVIRONMENTAL BENEFITS

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Chapter 1

Introduction

This research investigates business internal carsharing [BICS], a concept where businesses replace the idea of having one leasing car per employee by having a pool of cars which all employees can flexibly share with each other through bookings. One incentive for the businesses is to make business related car ownership and travel more efficient. BICS already makes a step in the right direction, since cars are assumed to stand still less than in the traditional leasing situation. However, the underlying assumption for this research is that BICS at this point does not capitalize its full potential. Therefore, the case of a specific BICS concept is analyzed to reveal the current inefficiencies, which arise from a high disparity of the utilization between peak and low moments. The research further investigates opportunities to reduce the inefficiencies and how revenue management concepts could be of help for a possible implementation. Benefits of a possible implementation are shown, and the feasibility of such an implementation is discussed.

1.1 WeGo

This research was conducted in combination with an internship at WeGo; An Amsterdam-based scaleup company, facilitating car sharing technology *in the business market.*

WeGo equips vehicles with a hardware device and connects it with the vehicle's central locking mechanism and immobilizer. Furthermore, the device has a GPS tracker and can extract different kinds of data form the vehicle. Via a sim-card in the device, communication between an online platform and the vehicles is enabled. This connection is used to receive data from the vehicles and to send commands directly from the system or a mobile app. Users can book vehicles with the system and get access to a virtual key of the booked vehicle for a specified amount of time (i.e., a booking period). With this virtual key in the mobile app, users can lock and unlock the vehicle during the duration of their booking.

Most customers are using WeGo's car sharing technology for a flexible use of their car fleets. Traditionally, companies assign one (lease) car to one employee. A drawback of this system is a low utilization of the cars related to the company and a high demand for parking space. When an employee is not using the assigned car, it stands still and requires a parking spot. Modern car sharing technology enables decoupling of cars and employees, while offering a digitalized administration. When multiple employees have access to a pool of cars, in theory the total amount of cars related to a company can be reduced, through higher utilization of the existing cars, which also reduces the demand for parking space.

Part of WeGo's mission is to support a more efficient use of the available cars (in a city), to reduce the number of cars and demand for parking space, which creates more space (e.g., for recreational areas) and reduces carbon dioxide emissions. [36]

WeGo has a few customers who use their technology for a free-floating carsharing system, where the cars of a fleet do not have a fixed home location and can be parked anywhere within a defined area (e.g., a city or island) after usage. However, most of the customers use a stationary carsharing system. In this system cars have a fixed home location (e.g., a company's parking garage). Every usage of a car starts and has to end at this location. [5]

Independent from the carsharing system of the customer, WeGo's revenue model consists of implementation costs, regular monthly costs, and incidental costs. The implementation costs consist of setup costs for the platform, which depend on the specifics for the customer platform, and costs for the installation of the hardware in the cars, which are billed per car. The regular monthly costs consist of a monthly license cost for the WeGo system and service costs, which are billed per car and depend on the services which are included in the customers subscription. The incidental costs include everything not included in the regular monthly service costs (e.g., training sessions, customer specific development requests, report generation). For most customers the regular monthly costs based on the amount of cars is the main driver in WeGo's revenue model. Only for customers with very few cars the monthly license costs outweigh the service cost per car.

1.2 Research Purpose

WeGo collects data about the usage of the cars in their system but has no models for the quantitative analysis of this data. Such models could further their mission, to support a more efficient use of cars to achieve financial and sustainable benefits. They could reveal if the number of cars in a fleet can be reduced and quantitatively support other ways to optimize the use of car fleets. This research investigates concepts to support WeGo's mission. The goal is to develop a model, based on different research fields (e.g., revenue management). Although its nature is quantitative, the research also includes a qualitative part. This complementary part considers how realistic a practical implementation of the theoretical models would be and how problem owners could be convinced to support a more complex, but possibly more efficient/sustainable solution (e.g., by quantifying carbon dioxide emission reductions and financial benefits). This section establishes the framework of the research.

1.2.1 Hypotheses

To clarify the purpose of the research four hypotheses about BICS are formed. They pave the way for the central research questions (Section 1.2.3), give an indication for the related sub-questions (Section 1.2.4), and the relevant fields of literature (Chapter 2) for this research. A toy problem is used to graphically support the hypotheses.

H1 The current carsharing approach for business internal car fleets does not utilize the potential of modern car sharing technology. Therefore, benefits in respect to efficiency and sustainability are not as big as they could be.

H2 The current demand is fluctuating strongly, and fleets are designed to supply peak demand. Therefore, car fleets are often heavily underutilized.

H3 It is desired to cover peak demand. Therefore, possibilities to reduce the amount of cars in a fleet are low. Thus, to increase the possibilities for such reductions, the peak demand would have to be lowered.

H4 To even the utilization, extra demand would have to be created in periods of low demand.

Toy Problem

To show the meaning of the hypotheses a toy problem is introduced. It returns (in sometimes adapted forms) throughout the research for clarification.

Considering a situation as depicted in Figure 1.1. In this situation a car fleet with 5 cars in total is given. During one half of a certain time period 4 cars are in use and during the other half of the period only 1 car is in use. In this situation the peak demand would be 4 cars. Looking at the situation

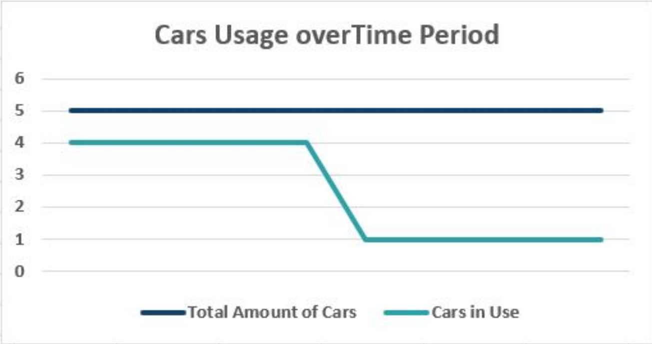

Figure 1.1: Toy Problem Example

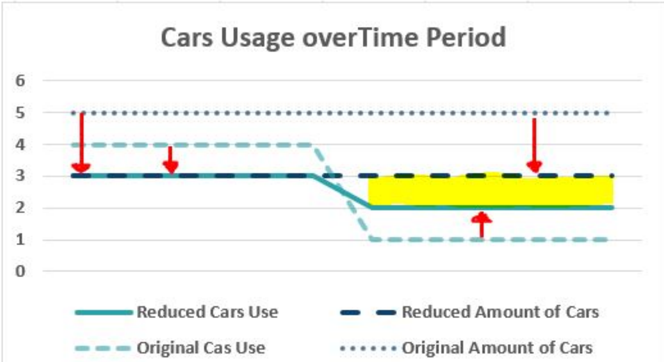

Figure 1.2: Toy Problem Improved Example

in a simplified manner, 1 car would never be in use and require parking space all the time. Half of the time even 4 of the 5 cars are not in use and would require parking space. Since the fleet includes 5 cars at this moment it might be possible to scrap one car and reduce the fleet to 4 cars. However, half of the time still only 1 car is in use. Assuming the fleet could be reduced from 5 to 4 cars, based on the peak demand, still 3 cars would not be in use and require a parking space half of the time.

If it would be possible to reduce the peak demand by 1, down to 3 cars, and to increase the demand by 1, up to 2 cars, during the period of low utilization (see Figure 1.2), the total amount of cars could be reduced by 2 (considering the start situation with 5 cars) and parking space would only be needed for 1 car.

1.2.2 Goal

Before presenting the central research question in the following section it should be thought about what this research aims to achieve. The first step is to validate the hypotheses, but more importantly the goal of this research is to find ideas for a more efficient and sustainable use of BICS. Furthermore, these ideas should be implementable in practice.

1.2.3 Central Research Question

How can a two-way demand regulation (reduction of peak demand and demand promotion in periods of low utilization) make the use of a business internal carsharing fleet more efficient and sustainable?

1.2.4 Sub-Questions

On the way to systematically answer the central research question, multiple sub-questions have to be answered. These sub-questions can be grouped in three categories, depending on which part of the central research question they concern. The first category focuses on fully understanding the situation on hand, which is the environment for the central research question. It is called the "Ist" - category. The second category focuses on the problems, which the "Ist" - situation presents in respect to the central research question. It is called the "Bottlenecks" - category. The third category focuses on finding solutions for the "Ist" - situation and its "Bottlenecks". It is called the "Solutions" - category.

In the following the sub-questions belonging to the described categories are listed. Their order is based on where they stand on the road map to answering the central research question. Directly under every sub-question an approach to how it is answered can be found. A broader approach for the research follows in Section 1.5.

Ist

Q1 How are cars used in BICS?

This sub-question is answered in two parts. First in a qualitative manner, by looking into the booking behavior (reasons for bookings and timing) of employees based on a customer case in Section 1.3.2. Furthermore, quantitative insights from the analysis of the booking data of the same customer case in Section 3.3.2 offers the opportunity to reflect on the qualitative interpretation.

Q2 What is the utilization of cars in BICS throughout the week?

This quantitative sub-question is answered by analyzing the booking data of a customer case. Chapter 3 discusses this analysis. Starting with some steps to prepare the data, this leads to Section 3.3 which presents results to answer this sub-question.

Bottlenecks

Q3 What is the disparity between periods of high and low demand throughout the week?

Using the findings to sub-question Q2 in Chapter 3, calculations are executed in Section 4.1 to answer this sub-question.

Q4 Why does this disparity occur?

To answer this sub-question, the reasons for the findings, regarding the disparity, are discussed in Section 4.2 under reference to Section 1.3.2, which discusses the way BICS fleets are used.

Q5 Which inefficiencies are caused by the demand disparity?

In Section 4.3 areas affected by the demand disparity are identified and the caused inefficiencies are displayed with the support of a toy problem.

Solutions

Q6 Which options are there to reduce peak demand?

Literature, about how to reduce car travel in general, is considered in Section 2.1 and related to the topic of this research in Section 5.1 to identify options for the reduction of peak demand. The options are grouped in two main approaches.

Q7 Which options are there to increase demand in periods of low utilization?

As for sub-question Q6, literature is considered (Section 2.2) and related to this research in Section 5.2 to identify options for the increase of demand in periods of low utilization. The options are again grouped in two main approaches.

Q8 What is a possibility to model a two-way demand regulation approach implementation?

An approach to use revenue management concepts to model an implementation is discussed in Section 5.3, to treat this topic.

Q9 What are the benefits based on the applied model?

To answer this sub-question a comparison is drawn to the issues of the current use of business internal car fleets (Section 4.3) and the respective benefits are identified from the literature (Section 2.3 and displayed with a toy problem.

Q10 What are thresholds against a practical implementation of such an approach?

In Section 6.2 different challenging topics are discussed and partly supported by literature, to get an understanding of the feasibility of a practical implementation.

Q11 How can these thresholds be overcome?

In Section 6.3 the threshold areas mentioned in Section 6.2 are discussed from a different perspective to see how they could be faced.

1.2.5 Deliverables

During the conduction of this research several valuables are acquired. These are the following deliverables:

- Analysis of the booking data / BICS usage of a specific WeGo customer case, which presents insights applicable to other WeGo customers.
- Insights in measurements to reduce and increase demand of BICS.
- An introduction of revenue management and a possible implementation strategy to carsharing.
- A literature-based summary of benefits from improving BICS and related thresholds, which could be used to convince stakeholders.

1.2.6 What is in it for WeGo?

The revenue stream of the business model, applied by WeGo, is partly based on monthly payments per vehicle. Intuitively this might sound contradicting with the goal of this research. Regarding the described purpose of this research, a wishful outcome would be to generate advice, which leads customers of WeGo to the decision to shrink their car fleet. This would lead to less vehicles in the WeGo system and thus less revenues for WeGo. However, in the market for internal sharing of company cars the prospect of making the use of cars in a fleet more efficient (possibly reducing the amount of cars) is one of the main selling points for WeGo. If this research shows how WeGo is able to help companies to increase the efficiency of their car fleet, WeGo might be able to attract more customers. The total revenues would increase by slightly decreasing the revenues per customer but increasing the amount of customers. Furthering the idea of carsharing would promote the market and increase WeGo's share in it.

Given the described contradiction, there is a conversation within WeGo about changing the business model. A different revenue stream might be more beneficial if WeGo successfully reduces the amount of cars in their customers fleets and this prospect would be more believable for customers.

1.3 The Case: Municipality of Amsterdam

The Municipality of Amsterdam is one of WeGo's oldest and biggest customers. Therefore, a lot of data has been collected, since the WeGo system was implemented. This makes the Municipality of Amsterdam a relevant customer case. Its data is chosen to build this research around. The Municipality of Amsterdam is introduced in this section and Chapter 3 is dedicated to analyzing the respective booking data of this case.

1.3.1 Carsharing in the Municipality of Amsterdam

The Municipality of Amsterdam is a public entity. Therefore, every spending and the way, in which entity property is used, is hold accountable by the taxpayers [18]. Furthermore, a Municipality has a role model function when it comes to sustainable innovation. The Municipality of Amsterdam showed its commitment to this role by signing an energy agreement for sustainable growth together with several other Dutch organizations in 2013 [33]. This agreement discusses ten 'pillars' for a transition towards a more sustainable future. One of these pillars focuses on mobility and transport. Being a public entity and having the mentioned role model function, a municipality can not only introduce laws and regulations supporting sustainable development. It also has the responsibility to look for ways of internal innovation to become more sustainable. The Municipality of Amsterdam sees carsharing as a topic, which can be used regarding both responsibilities. This was expressed by joining the Green Deal, a collaboration of Dutch municipalities and private companies with the common goal of accelerating the carsharing industry to reduce the strain of cars on the environment [25]. One part of this is to introduce regulations to increase the public interest in carsharing (e.g., increasing inner city parking fees for privately owned cars and reserving parking space only for shared cars). The other part is to introduce the carsharing principle for the own car fleet.

The Municipality has multiple fleets, which are separated per location, functionality, and/or departments. Some vehicles are used for traveling to appointments, others have more specific functionalities like the garbage trucks. About 900 vehicles of these different fleets of the Municipality of Amsterdam are equipped with WeGo's technology. Not all of them are used as shared cars, via employee bookings. A big part of the fleets, e.g., the garbage trucks, are utility vehicles, which are equipped with WeGo's technology mainly for administrative reasons. With these vehicles WeGo's technology is not used for carsharing, but to guaranty a transparency towards the taxpayer and to fight fraudulent use of the vehicles. Only a small part of the vehicles of the Municipality of Amsterdam is used as shared cars, via employee bookings. This research focuses on the data belonging to the bookings for these cars and the respective trips. Due to the strict fiscal regulations for public entities, the data of the Municipality of Amsterdam has to be stored for 5 years. This research focuses on the booking data of a 3-year interval from the 1^{st} of September 2014 till the 31^{st} of August 2017.

1.3.2 Use of Shared Cars in Business Internal Carsharing

Focusing only on the shared cars within the fleets of the Municipality of Amsterdam, their use via employee bookings is in some parts representative for BICS (of companies in the WeGo system) in general. Therefore, the use of shared cars within the Municipality of Amsterdam can be used to answer Sub-question Q1.

Since the cars are owned by the company and meant to offer business related mobility for a large group of employees, the cars can (in some cases only) be booked for business trips. Often these trips are related to one or multiple appointments with customers or suppliers, but they can also be used for deliveries or pickups. These trips are mainly executed during the working hours of employees. There are some scenarios where bookings might also be scheduled outside of the regular working hours of employees. For example, when an employee has a task which requires to book a car for a period of multiple days, or tasks which are related to events in the evening.

Furthermore, the use of shared cars with the Municipality of Amsterdam is subject to the restrictions of the implemented stationary carsharing concept. The use of a car / a booking has to be ended by returning the car back to its pickup location (its home location).

1.4 Definition: Vehicle Demand and Utilization

This research focuses on the demand and utilization of the vehicles in BICS concepts. Therefore, consistent definitions for demand and utilization, as used throughout the research, are established before going further with the research and tackling the sub-questions.

The definitions used for demand and utilization in this research are mainly driven by the technical functionalities of WeGo's reservation system (and the use thereof) and the specifics of the available data. The discussion of the data in Chapter 3 should further the understanding of the chosen definition.

As mentioned before, BICS systems on WeGo's platform are stationary. Employees book a vehicle for a certain period of time, they start the booking by picking the vehicle up at its specific home location, they use the vehicle and return it to the vehicle's home location before the end of the booking period. When an employee has a vehicle in use it might stop multiple times for longer periods at different locations. Although, the vehicle is not driving it is still utilized by the employee who booked the vehicle, since the stationary carsharing system and the booking prevents other employees to use the vehicle. Therefore, the utilization of a vehicle is defined as the period of time the vehicle is booked. In this sense it does not matter when the vehicle is driving or standing still during the booking period. When talking about efficiency and sustainability this definition is somewhat restricting, since in a theoretically optimal situation the vehicles would have to drive almost all the time to achieve maximal efficiency. However, for the scope of this research this restriction is accepted, since it aligns with the given reality. Furthermore, the data used for the research is based on the bookings. Although, data about the specific movement of vehicles exists, it would be harder to access and given its structure more difficult to analyze and interpret than the booking data.

The definition of demand is mainly driven by the needs of the ones who create it. With carsharing, demand on an abstract level can be seen as the wish for mobility. A vehicle might be the preferred solution for the wish for mobility, but in some cases can be substituted by other means (e.g., public transport or a bicycle). Therefore, on a less abstract level the demand in the context of carsharing is mainly seen as the need for availability of a vehicle. Given the specifics of the stationary carsharing system, the need is not only to have a vehicle to get from A to B. The need is to have the availability of a vehicle ensured for a specific period of time, during which the user can go from A to B and after some time return to A. Therefore, demand can be defined as the need for a vehicle for a predefined period of time.

1.5 Plan of Approach

This introduction chapter defines the settings of this research. In the following the research is structured to answer the sub-questions in their respective order, to bring the research to a conclusion. The research starts with a literature review (Chapter 2) of topics, indicated by the hypotheses and sub-questions, which are relevant for following parts of the research. Before the knowledge gained from literature is used, the focus is on understanding BICS thoroughly. After the first introduction of the Municipality of Amsterdam case and a discussion of how the respective vehicles are used (Section 1.3), the belonging booking data is analyzed (Chapter 3). Based on the gained insight, inefficiencies with the current use of BICS are further analyzed and discussed (Chapter 4). Switching gears, knowledge from the literature review is used to evaluate ideas to improve the current use of BICS and revenue management is introduced to model an implementation of the improvements (Chapter 5). To understand the feasibility of such an implementation potential benefits, based on literature insights, and thresholds are discussed (Chapter 6). The implementation options and their implications are followed by recommendations about choices supporting a desired outcome (Chapter 7). All subjects conducted throughout the research are concluded and implications for future research are discussed to round of the research (Chapter 8).

Chapter 2

Literature Review

The previous chapter establishes the context in which this research is conducted and introduces the research. To start the research, this chapter reviews literature, relevant for different parts of this research. Therefore, the gained insights come back later throughout this research. The topics reviewed are based on the hypotheses (Section 1.2.1) and sub-questions (Section 1.2.4) stated in Chapter 1. To find solutions to the assumed inefficiencies of BICS Section 2.1 reviews measures to reduce travel demand and Section 2.2 reviews possibilities to increase demand. Section 2.3 reviews overall benefits of public carsharing, which are later used to establish an incentive for improving BICS.

2.1 Reducing Travel Demand Peaks

Since cars are responsible for a significant part of total energy consumption [24] and cause a major strain on the environment [12], there is a strong public incentive for measures to reduce car travel demand. Furthermore, business travel is a major contributor to rush hour traffic [11], which establishes an incentive for this research to include a review of measures for businesses to reduce the car travel related to them. Besides the public incentive to reduce business travel, reduction measures might translate to the peak demand, which is hypothesized to be a driver of the utilization inefficiencies of BICS (see Hypotheses H2 and H3 in Section 1.2.1). Therefore, this section focuses on measures to reduce car travel.

Research on script-based driving choices indicates how choosing driving as means of travel is influenced by habits [6]. Therefore, the question would be how to break these habits and either influence the user to choose a different means of traveling or not travel at all. Steg and Vlek [30] catalogued a list of push and pull travel demand management (reduction) measures, which are listed in Table 2.1.

Table 2.1: Travel demand management measures ordered from push to pull based on [30]

Taxation on cars and fuel
Closure of city centers for car traffic
Road pricing
Parking control
Decreasing speed limits
Avoiding major new road infrastructure
Teleworking
Land use planning encouraging shorter travel distances
Traffic management reallocating space between modes and vehicle
Park and ride schemes
Improved public transport
Improved infrastructure for walking and biking
Public information campaigns about the negative effects of driving
Social modeling where prominent public figures use alternative travel modes

Table 2.2: Measures for reducing car use listed from more to less effective based on [32]

More reliable public transport services
Much cheaper transport
Shorter overall journey times on public transport
Shorter interchange times on public transport
A ticketing policy so that 1 ticket covers different forms of transport
More readily available information about transport
Vouchers from employers to subsidize the cost of season tickets
Better cycling facilities
The closure of city centers to cars
Fewer places to park the car
More expensive petrol
Road tolls
Public information campaigns about negative effects of car use

While, it has been argued that the impact of the presented measures is not based on behavioral evidence [7], Stradling, Meadows and Beatty [32] collected a list of measures to reduce car use / increase use of other travel options and found empirical evidence for the effectiveness of the measures. They compared their findings with Steg's and Vlek's list and found that in general pull measures (positive connotated influence from other travel options) seemed to be more effective than push measures (negative connotated influence away from choosing to travel by car). The measures discussed by Stradling et al. listed from more to less effective, can be seen in Table 2.2.

While Stradling et al. [32] only found empirical evidence for measures to possibly reduce car usage, Rose and Ampt [27] implemented a travel awareness campaign for reducing car use and successfully measured a relevant reduction. Studies which applied such a campaign or comparable methods on groups of multiple households in the United Kingdom and Australia resulted in reductions in car use of about 10 - 20 % [37][27]. Although the conducted studies focused on the car use of households, Rose et al. imply that the method would also be applicable for business related car use. The main critic on such a travel awareness campaign is the work intensity it requires [37][27]. Furthermore, the impact on business related travel is not clear. As Katzev points out [12], most campaigns and other approaches to reduce solo car travel fail to achieve relevant results.

Additionally, to measures for reducing travel demand, Hensher [11] suggests that flexible working practices, such as compressed working weeks and flexible start/end times, are promising ways to shift business related travel throughout the week, which would at least spread the demand more evenly.

2.2 New Demand Sources for Business Internal Carsharing

Due to the public incentive to reduce car travel (mentioned in the previous section), arguing for research related to increasing travel demand seems daring. However, when the problem is to optimize the utilization of car fleets, measures to reduce the current overall usage (and thus the peak demand) have questionable effectiveness [12], generating additional travel demand in underutilized periods becomes a relevant subject (see Hypotheses H2 and H4 in Section 1.2.1). Therefore, this section reviews literature which gives insights on where to search for sources of this kind of demand.

The assumption that there is demand for the cars of a business internal fleet, outside the periods during which most of business related trips takes place, is based on the same assumptions as for general public carsharing demand. Nowadays paying for the temporary access to a service (i.e., car use) is more relevant than ownership of the respective product (i.e., the car) [1][23]. The interest in carsharing is mainly based on an only occasional need for a car and the inconveniences of owning a car would have (e.g., the cost of owning a car) [12][23]. In general demand for public carsharing does not occur during common working hours, since public carsharing is rather used for private, social, and recreational travel than for work related travel [3]. Furthermore, the commonly applied hourly rates for carsharing generally makes it unattractive for commuting [15], since the ratio between booking and actual usage duration is not favorable in the case of commuting.

When it comes to the origin location of the demand sources for public carsharing, the proximity of the cars to the homes of users seems to be of relevance [3].

2.3 Benefits of Public Carsharing

The previous two sections focus on literature, giving insides on how to improve the utilization of BICS. This section focuses on literature, showing incentives for optimizing BICS: the environmental benefits of carsharing. Rabbitt and Gosh [24] gave an extensive summary of the benefits from carsharing: "Active subscription to a car sharing service (CSS) changes individual travel behavior which impacts on: the greenhouse gas emissions of travel, levels of public transport use, the times at which people travel, levels of private car ownership, distances traveled in private vehicles, and levels of cycling and walking". This literature review focuses on these topics and discusses them in three parts: reduction of private car ownership (Section 2.3.1), reduction of car travel (Section 2.3.2), and results for the environment (Section 2.3.3).

2.3.1 Reduction of the Amount of Active Cars

As established in the previous section, there is an incentive to prefer temporary access to a car above owning one. Carsharing offers this temporary access and therefore has the potential to make car ownership obsolete in some cases. Extensive research exists, which measures how many privately-owned cars can be replaced by one shared car. While all studies show reductions, there is a lot variety. The literature considered for this research mentions that one shared car can replace between 5 and 23 privately owned cars [2] [17] [12] [15] [16] [9] [28]. In all cases these values were found by measuring how many carsharing subscribers sold a car or avoided/postponed buying a new car, which led to reductions in the average amount of cars owned per participating household. Although, there is literature summarizing the results from multiple carsharing projects, no literature was found focusing on explaining the difference in impact on car ownership. Factor which seem to play a role are: sophistication of public transport, area density, and user needs.

2.3.2 Reduction of Car Travel

Next to a reduction in the amount of private cars owned, literature also indicates that carsharing members in average travel a shorter yearly distance with a car [16] [23] [9] [28]. Again, the values found by different studies have a significant variance. They start at a yearly travel distance reduction of 27 % and go up to 50 %. There was only one case which could not confirm such reductions, which is assumed to be related to the availability of public transport and the overall infrastructure [12]. As for the reduction in car ownership there were no statistical comparisons found in literature, which try to explain coherences. However, the important factors (sophistication of public transport, area density, and user needs) seem to be related. What all studies have in common is a majority of users who increase their yearly travel distance, which is compensated by a minority of users who significantly reduce their yearly travel distance and therefore leads to the mentioned overall reduction. This distribution is directly related to the history of users. In all studies more than 50 % of new users come from car-less households. Literature indicates, especially carsharing households, which exchanged ownership for access, chose public transport, biking or walking as means of travel more often and become overall more conscious about their travel behavior.

2.3.3 Environmental Results

Literature found that carsharing helps to reduce carbon dioxide emissions with statistical significance [2] [15] [16] [16] [9] [28] [24]. While the reduction of car travel and amount of cars in circulation has direct implications for the environmental strain, carsharing has additional less direct benefits. The privately-owned cars shed due to carsharing membership are in general older than, the cars of a carsharing fleet. In a North American study, cars shed due to carsharing were in average about 17 years old (with a median of 11 and mode of 10) [15]. Cars in a carsharing fleet are often younger and therefore more fuel efficient [16]. In most cases their functionality allows them to be smaller and low-polluting [2]. The superiority of carsharing cars have been measured in different studies. In the previously mentioned North American study, the shared cars were in average 4.25 kilometer per liter more efficient than the respectively shed cars [15]. In a Swiss study, shared cars were found to be 26 % more efficient than the average car in Switzerland, which translated to 25 % less carbon dioxide emissions of these cars and resulted in a yearly reduction of 2,900 kilogram less carbon dioxide emission per active car sharing customer [9]. Over all of Europe, the carbon dioxide emissions through joining carsharing were estimated to reduce 39 % to 54 % per user [28]. An approach to model the full impact of carsharing ("what physically happened with carsharing, as well as what would have happened otherwise in the absence of carsharing") resulted in a greenhouse gasses reduction of 840 kilogram per carsharing household per year [16]. Furthermore, "carsharing members also report a higher degree of environmental awareness after joining a carsharing program" [28]. "Overall a population with [carsharing members] has a lower level of car-dependency and transport related [carbon dioxide] emissions than a similar population without access to [carsharing]" [24].

Besides the potential emission reductions, carsharing also has other benefits for its environment. Carsharing offers cost efficient access to people with an income, not sufficient for owning a car (e.g., low-income households and students), which can prevent exclusion and enables a more active lifestyle [28]. Furthermore, "reduced vehicle ownership may mean that less residential parking has to be provided, and businesses may be able to lease fewer parking spaces" [17], which creates space for recreational areas or housing.

2.4 Chapter Conclusion

This chapter reviews literature to build a foundation for other parts of the research. Section 2.1 reviews literature about reducing travel demand in general, which is related to the inefficiencies of BICS in Section 5.1. Section 2.2 reviews literature related to potential new demand sources for carsharing, which is used in Section 5.2 to introduce options to increase the utilization of BICS. Section 2.3 reviews literature about the benefits of carsharing, which is used in Section 6.1 to support the possible implementation of new concepts to improve BICS. Before the insights from literature are used, the research focuses on its "Ist" - situation and inefficiencies of BICS in Chapter 3 and 4.

Chapter 3

Analysis of Case Booking Data

For now, the literature reviewed in the previous chapter is put to rest (until Chapter 5). Before the insights from literature are resumed, the research focuses on understanding how BICS is used and in which inefficiencies this results. This chapter introduces the core of this research. It focuses on the "Ist" - situation, based on the Municipality of Amsterdam case. At first the structure of the case data is introduced in Section 3.1. The data set is reduced to single out relevant parts which can be used to gather relevant insights about the "Ist" - situation in Section 3.2. Before going into detail, in Section 3.3 first analyses are executed to get a first indication form the "Ist" - situation and reflection on the assumptions are formulated in Section 1.2.

3.1 Presentation of the Case Data

As previously mentioned the data considered is the booking data from a specific case, The Municipality of Amsterdam. The booking data includes the following information: Booking ID, Start time of the booking (as defined when the booking was placed), End time of the booking (as defined when the booking was placed), Booking status (completed, canceled, running, accepted), User (user name of the employee, related to the booking), Fleet manager (person responsible for the car), Car (license plate of the car), Purpose (business, private, commute). An example of the booking data table can be seen in Figure 3.1 . The booking data is stored in instances per booking, which include information like its start and end time. To retrieve statistics about demand / car utilization the data is transformed in a way which represents how many cars were occupied during defined time steps.

3.2 The Relevant Data Set

Before the booking data of the past three years could statistically be analyzed, the relevant data had to be singled out. Some of the bookings and cars do not belong to actual bookings but were created for (development) tests. Furthermore, the data had to be grouped into consistent data sets. Employees and cars are linked to each other through organizations. Cars belong to different home locations in the stationary carsharing system of the Municipality of Amsterdam. Employees only have access to the cars of the organizations they are registered under. Therefore, not all employees might have access to the same cars (The concept of organizations is further explained in Section 3.2.1). Home locations of cars and access of employees might even have changed during the three years under review. These facts had to be considered while preparing the data.

Id	Begin	Eind	Status	Gebruiker	Vlootmanager	Auto	Doel
2889	2014-09-02 08:00	2014-09-02 12:00	Afgerond	[redacted]	[redacted]	[redacted]	Zakelijk
2896	2014-09-02 08:24	2014-09-02 09:39	Afgerond	[redacted]	[redacted]	[redacted]	
2823	2014-09-02 09:00	2014-09-02 17:30	Afgerond	[redacted]	[redacted]	[redacted]	Woon-werk
2312	2014-09-02 09:00	2014-09-02 16:00	Afgerond	[redacted]	[redacted]	[redacted]	
2857	2014-09-02 09:30	2014-09-02 16:15	Afgebroken	[redacted]	[redacted]	[redacted]	
2897	2014-09-02 09:45	2014-09-02 16:30	Afgebroken	[redacted]	[redacted]	[redacted]	Zakelijk

Figure 3.1: Booking data example

3.2.1 Grouping

For the grouping of consistent data sets two factors, the home locations of the cars and the access of employees, had to be considered. The purpose of the grouping is to find consistent data sets in respect to demand / car utilization. The demand is created by the users who are at one location and want to get to a different location; A need for mobility, a vehicle at the location of demand. This is measured through the booking data from the system, which creates some deviation from the actual demand. There are no measurements of over-demand, when a user needs a car while all cars, fulfilling the criteria of demand, are already occupied. The results reveal whether this is an issue.

An organization can have different home locations (e.g., different parking garages). Cars are assigned to a specific home location within their organization, but users can book cars at all home locations within the organization they are registered under. Therefore, users can create demand at different locations, but the cars have fixed home locations. It is previously indicated that cars can be relocated to a different home location. These relocations happen very seldom and are long term decisions. There are a few cases where vehicles were relocated, because they were almost never booked. The vehicles then were relocated to a different home location, where all cars seemed to have a very high utilization. The information on hand, about the home location of the cars, is based on their last home location. Since the few cars, which were relocated, only created very little amounts of booking data before the relocation, the data created during the period of review is handled as if the cars had been at their latest home location during the whole period. The relocation of cars can be neglected, since its influence is not relevant. Furthermore, the few bookings created at a different home location before the relocation can be interpreted as compensation for possible missing measurements of over-demand at the new home locations with a higher demand.

A possible approach to find out the consistent data sets would be to look at which users book which cars and separate linear independent sets. However, a simpler approach based on the system properties and nature of demand creation is used to determine the consistent data sets. As mentioned before, the system is structured in multiple organizations, which have a specific number of home locations, to which cars are assigned and where demand can occur. The cars in the system are fixed to these locations (since relocation is neglected), but the users are not. A user most of the time creates demand at the same locations, e.g., the head office of his department, but there are cases where this user might create demand at a different location (belonging to the same organization), e.g., when working on a project with a different department. The shared car fleet of the Municipality of Amsterdam is rather homogeneous. All the cars which employees can book have more or less the same specifications. The functionalities of cars are therefore not considered as separating factor. When employees create demand, book a vehicle, the determining factor is availability on location. The demand for a car from an employee on a location somewhere in the east of Amsterdam cannot be satisfied with a car at a home location somewhere in the west of Amsterdam. Furthermore, even if a car is at the location of demand, it can only satisfy this demand, when the respective user has access to the car / is registered under the same organization. This being the dominating factor for the creation of booking data, leads to the decision to separate the data sets first according to the organizations of the cars and on a second level based on the home locations of the respective cars belonging to the data inputs.

In the analyzed booking data 71 different cars occur. Nine of these can be identified as test cars and all data belonging to them is not considered at all. Of the 62 remaining cars, not all are active anymore or were active during the whole period of review. Still the data belonging to these cars (15,595 bookings) is included, since during the creation of the data the cars were part of the consistent data sets. Theses 62 cars are divided over 20 home locations and six different organizations. One of the organizations, called FBA (standing for Facilitair Bedrijf Amsterdam), accounted for 52 of the pool cars, almost 84 % (see Figure 3.2), and 14,967 of all bookings in the considered booking data, almost 96 % (see Figure 3.3). The specific amounts of cars and bookings per organization can be seen respectively in Tables A.1 and A.2 in the Appendix.

Since it is by far the biggest organization, when it comes to cars and bookings, the FBA is the only organization considered. However, the data belonging to the FBA still has to be clustered in

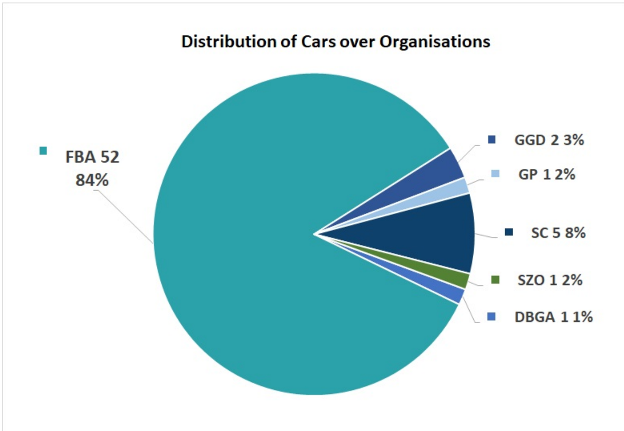

Figure 3.2: Distribution of Cars over the 6 Organizations of the Municipality Amsterdam

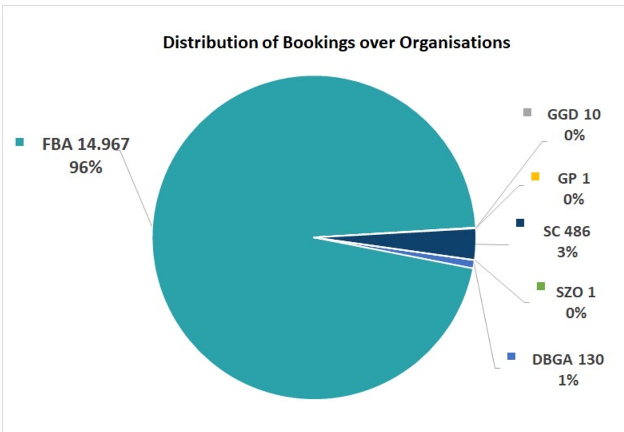

Figure 3.3: Distribution of Bookings over the 6 Organizations of the Municipality Amsterdam

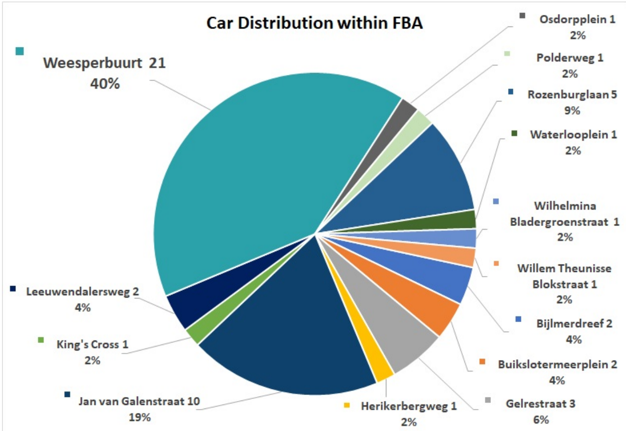

Figure 3.4: Distribution of Cars within the FBA organization

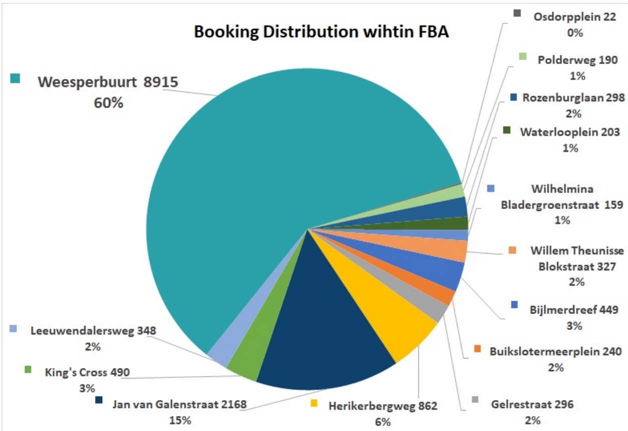

Figure 3.5: Distribution of Bookings within the FBA organization

respect to the home locations. The cars of the FBA are spread over 17 home locations. Since some of these are in walking distance of each other, they can be considered to belong to the same consistent data set / cluster.

3.2.2 The Relevant Cluster

Of the 17 home locations mentioned under the FBA organization, four are located in the Weesperbuurt in Amsterdam each with at most 5 min walking distance from each other: Lepelkruisstraat 46, Weesperplein 8, Weesperstraat 113 and Weesperstraat 430. Due to their proximity the assumption is made that cars at these four locations are able to satisfy the same demand. Therefore, they are considered as one cluster. Of the 52 cars of the FBA organization (62 overall), 21 are mentioned to belong to this cluster (see Figure 3.4). These cars account for 8,915 instances of the booking data, about 60 % of booking data belonging to the FBA (see Figure 3.5) and 57 % of all relevant booking data. The booking data of the dominant Weesperbuurt cluster is therefore chosen as the most relevant consistent data set and used as reference point for the remaining research. The specific distribution of cars and bookings within the FBA organization can be seen respectively in Tables A.3 and A.4 in the Appendix.

As previously mentioned, car fleets can change over time. Lease contracts end and are replaced, cars breakdown, new cars are introduced, etc.. In order to get an indication of the supply level (i.e., the amount of cars which could be booked) of the Weesperbuurt cluster at any point in time during the reviewed period, the start of the first bookings and end of the last bookings of the cars in the booking data is looked upon. The amount of cars in the Weesperbuurt during the reviewed period

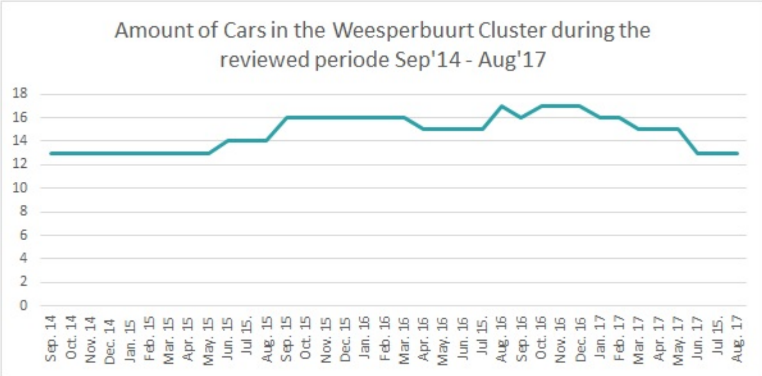

Figure 3.6: Flow of the Amount of Cars in the Weesperbuurt Cluster

varies between 13 and 17 cars with an average of 14.75. This only considers entrance into and exit out of the cluster of cars. It does not consider intermediate periods of unavailability (e.g., for maintenance). The development of the amount of cars in the Weesperbuurt cluster from September 2014 till August 2017 can be seen in the graph in Figure 3.6.

WeGo is developing a new platform, which enables a more complex organization of grouping structures and the belonging data. Unfortunately, the data on hand had to be collected from the first platform, which does not have these features. Therefore, the grouping and data separation had to be done manually and needed some research. After the relevant cluster was found, Excel's filter function was sufficient for separating the data.

3.3 Vehicle Utilization Analysis

In the following the data belonging to the Weesperbuurt Cluster is analyzed, without overspending time on accuracy, to gather relevant insights. The booking data presented in the previous sections has some issues regarding the accuracy of the executed analysis, which is discussed in Section 3.3.3.

3.3.1 Approach

In Section 1.4 vehicle utilization is defined as the time a vehicle is unavailable due to a booking. In the definition it is not mentioned, that the booking system automatically adds short periods of unavailability before and after a booking for a vehicle. These short periods can be seen as time buffers and are normally 15 minutes long. During these buffers the respective user can already / still use the vehicle. The buffers have the purpose of allowing some uncertainty, in case a user arrives too early to pick up the booked vehicle or has delay during his return to the home location. For the analysis these 15-minute buffers before and after the booking period are added to the utilization periods of vehicles.

The interest of the analysis is to understand how shared cars of the Municipality of Amsterdam are utilized throughout the week. For this purpose, the week is split up in time slots of 30 minutes. For a given booking instance of the data set, the buffers are added to the scheduled booking period and it is calculated how many 30-minute time slots the booking utilized the respective vehicle. The utilization of a vehicle on a certain time slot is binary. If a booking only utilized a vehicle for a part of a time slot, the time slot is still considered as fully utilized (e.g., a booking for vehicle X with a booking period (including buffers) of 1 hour 50 minutes utilizes vehicle X for 4 to 5 time slots). Obviously, this could lead to double utilization of one time slot by two consecutive bookings, but the binary interpretation of the utilization of a vehicle serves as simplification here and neglects this conflict. From this time slot approach per vehicle it is condensed how many vehicles are utilized during the 30-minute time slots throughout the review period of 3 years.

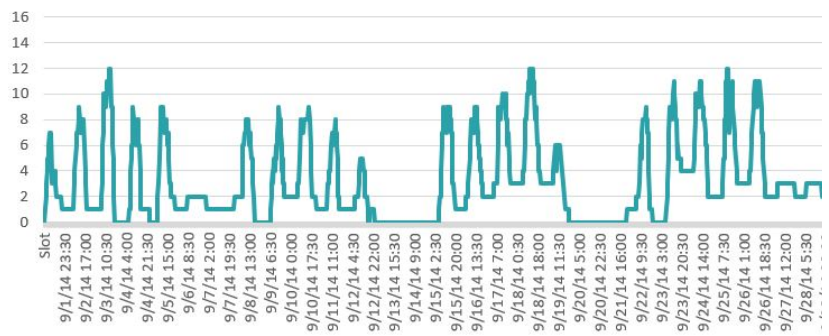

Figure 3.7: Example from the First Insights about Vehicle Utilization per Time Slots

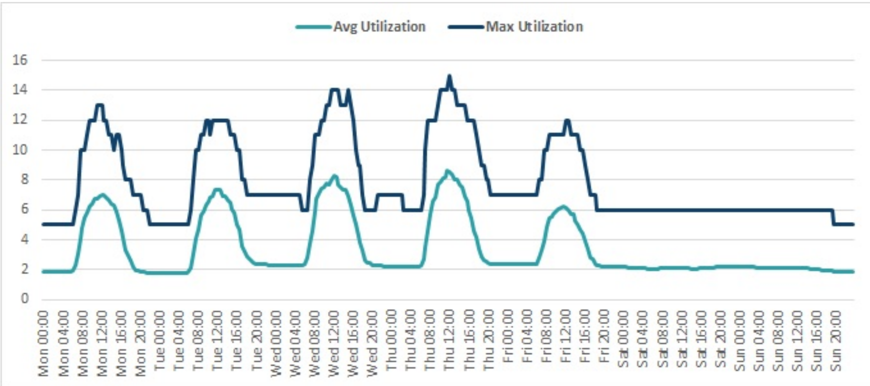

Figure 3.8: First Insights about Average and Maximum Utilization per Time Slot in a Week

3.3.2 Results

Looking at how many vehicles are utilized per time slot during the review period of 3 years (see Figure 3.7 for an example) a certain pattern can already be noticed. This graphical representation reveals how vehicles are utilized a lot during daytime from Monday to Friday but underutilized during weekends and evenings throughout the week. These results confirm the qualitative explanation of how employees use the shared cars, given in Section 1.3.2.

Without going too much into detail and accuracy about trends and correlations in the data set, for every time slot in a week the average and maximum utilization over the whole review period is determined. Figure 3.8 shows these average and maximum values of the vehicle utilization for the time slots in a week. The explicit average and maximum values per time slot can be reviewed in Table A.7 in the Appendix. In average from Monday to Friday a steep increase of the vehicle utilization is indicated during early office hours (starting around 7ish) till the utilization peaks around noon, followed by a steep decrease till the late office hours (ending around 18ish) and a constant low vehicle utilization on Saturday, Sunday and during the evening and early morning hours from Monday to Friday.

Although there are companies with a BICS concept, which might have a different utilization throughout the week (with a more even spread or peaks at a later point during the days) than what can be seen in Figure 3.8, the insights gained from the booking data of the Municipality of Amsterdam are representative for a majority of BICS concepts. The presented results therefore give a general answer to Sub-question 2).

3.3.3 Discussion of Accuracy

As previously mentioned there are some issues with the booking data, which could arguably cause an inaccuracy in the obtained results. Here three issues are pointed out and, in the following, argument-

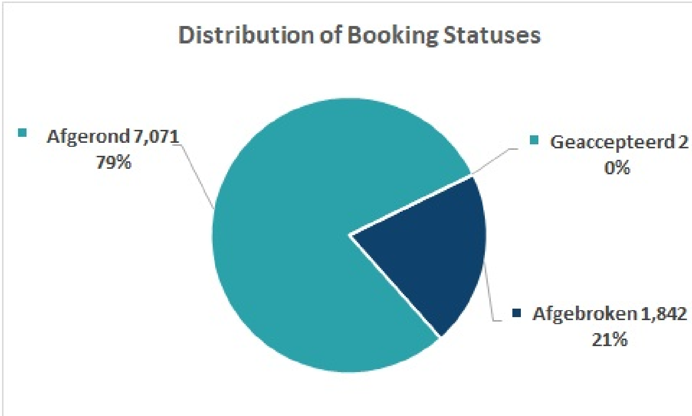

Figure 3.9: Distribution of Booking Statuses of the Weesperbuurt Cluster

ation in the respective order of the issues is stated.

Issues

I1 The biggest issue are booking instances, which are not seen as completed bookings and might not have caused the utilization of a vehicle as indicated by the booking period of the respective instance. As shown in Figure 3.1, each booking instance has a status. There are booking instances registered with a status which indicates the respective booking was canceled. Depending on the moment of cancellation (before, after the start of the scheduled booking period), these instances might not actually have caused the utilization (over the full booking period) of a vehicle. A consequence of including canceled bookings in the utilization could cause that multiple bookings are considered to utilize the same vehicle during overlapping time periods and a general higher level of utilization.

I2 Another issue is the inclusion of singularities within the utilization. In the situation on hand these are mostly constant low utilization values, caused by holiday periods during which less (sometimes no) employees work. Although these occur cyclic every year, they differ from the general utilization during the weekly time slots.

I3 Furthermore, the data analysis did not consider possible trends throughout the three-year review period. In Section 3.2.2 it is mentioned that the amount of cars available in the considered data set changed throughout the years (see also Figure 3.6). This and the possibility of a changing booking frequency throughout the years might have influence on the utilization throughout the years.

Argumentation

A1 To understand the impact of including canceled booking instances on the utilization results, the amount of canceled booking instances in comparison to the total booking instances considered can give some indication. In total 8,915 booking instances are considered. In these instances, three booking statuses occurred: "Geaccepteerd" (confirmed), "Afgerond" (completed) and "Afgebroken" (canceled). As can be seen in Figure 3.9 and Table A.5 in the Appendix, most of the bookings, 79 %, are registered as completed ("Afgerond"). It is assumed that their booking periods can accurately be assumed to fully utilize a vehicle. Due to the small amount, there is no attention payed to the "Geaccepteerd" booking instances. Only the 21 % of booking instances registered as canceled ("Afgebroken") might cause an inaccuracy for the utilization results. 21 % is a reasonable large part, however basically everything else is considered to be accurate. This ratio takes away from the impact the included canceled booking might have. Especially since it is not completely clear what part of the respective booking periods was actually utilized. Furthermore, the used binary interpretation of utilization of a vehicle during a time slot neglects the impact of multiple canceled bookings on the same vehicle and time slot.

Furthermore, it might be a reasonable assumption that canceled bookings are be more or less randomly distributed over all time slots throughout the week and not only concentrate on specific time slots. Therefore, the worst-case impact of including the canceled booking instances is that the average utilization is slightly higher, than the actual utilization, for all time slots throughout the week. This research is interested in the general trend in utilization throughout the week, which should not be dramatically influenced by including canceled booking instances, since (if they have any distorting impact) they are evenly increasing the average utilization of all time slots throughout the week.

A2 Since the reviewed data set included bookings form the past three years, its size should be big enough for singularities not to have a relevant impact on the accuracy in comparison to the whole data set. Furthermore, longer singularity periods (e.g., period from Christmas till New Year's) can be assumed to influence all time slots throughout the week more or less equally. Here the same reasoning as for the previous argumentation applies: longer singularity periods should not dramatically influence the general trend of the utilization throughout the week.

A3 Since the reviewed fleet of the Municipality of Amsterdam can be assumed to have been used for the same functionalities (see Section 1.3.2), the general trend of the utilization throughout the week should not be influenced by trend changes throughout the years. A general increase or decrease in demand or capacity over the years could be possible, but this should influence the average utilization per time slot in a similar way for ever time slot and therefore not the general trend of the utilization throughout the week.

In general, an inaccuracy of the results in Section 3.3.2, due to considering all booking instances as fully utilizing vehicles over the respective booking period, cannot be expelled. However, it can be assumed that the general trend of the utilization throughout the week, which this research is interested in, stays accurate, since possible inaccuracies seem to influence the average utilization for every time slot in the week in a similar way.

3.4 Chapter Conclusion

This chapter establishes a full understanding of the "Ist" - situation, answers Sub-question Q2 (Section 1.2.4) and confirms Hypothesis H2 (Section 1.2.1). The analysis of the booking data is translated into an average utilization per 30-minute time slots throughout the week. While this analysis is based on a subset of the Municipality of Amsterdam, the output indicates how BICS in general is used throughout the week and answers Sub-question Q2. Furthermore, the analysis shows that there is indeed a strong fluctuation of demand and therefore together with the knowledge from Section1.3.2 confirms Hypothesis H2. With the insights about the "Ist" - situation, in the following the respective inefficiencies are researched.

Chapter 4

Issues with the Current Use of Business Internal Carsharing

After forming a picture of the "Ist" - situation in the previous chapter, this chapter focuses on the "Bottlenecks" caused by the "Ist" - situation (the current use of BICS) in respect to the central research question. The "Bottlenecks" are related to the disparity between periods of peak demand and periods of low utilization, which is framed by three sub-questions. In this chapter one section is dedicated to answering one of these sub-questions. Section 4.1 includes calculations for answering Sub-question Q3. Section 4.2 reflects on the knowledge about the "Ist" - situation to answer Sub-question Q4. Section 4.3 investigates effects caused by the disparity, presented in Section 4.1, and uses a simplified version of the results to display the effects.

4.1 Demand Disparity

In Section 3.3 shows how demand for BICS behaves throughout the week. Peak demand seems to occur during office hours, especially around noon, from Monday to Friday and periods of low utilization are Saturdays, Sundays, and non-office hours (evenings and early mornings) throughout the week. This section looks further into the results found and the disparity within the utilization. For this purpose, three states are introduced: peak demand, transition, and low utilization. It is discussed which difference occurs between the demand ranges of the extreme states and it is determined which percentage of time the states cover. As mentioned in Section 3.3.3 the utilization values determined for the time slots throughout the week are not totally accurate. However, they give a good enough indication of the utilization trend throughout the week and this research is primarily interested in the general trend rather than details based of one case. Therefore, the demand disparity calculations are based on the averages determined in Chapter 3.

4.1.1 Utilization States

To form the three states (peak demand, transition, and low utilization) the range between the maximum and minimum values of the average utilization throughout the week, as presented in Table A.7 in the Appendix, is divided into three equal parts. Time slots with utilization values belonging to the upper third of the range fall into the peak state. Time slots with utilization values belonging to the lower third of the range fall into the low state. Everything in between is seen as transition state.

The maximum average utilization of any time slot throughout the week is 8.64 and is reached at 11:30 on Thursday morning. The minimum average utilization of any time slot throughout the week is 1.78 and is reached on Tuesday morning from 1:00 till 4:00. Given an upper bound of 8.64 and a lower bound of 1.79 the range is 6.86. Dividing this range into three equal parts means that each state has a range of 2.29. Resulting in the following lower and upper bounds for the ranges of the three states:

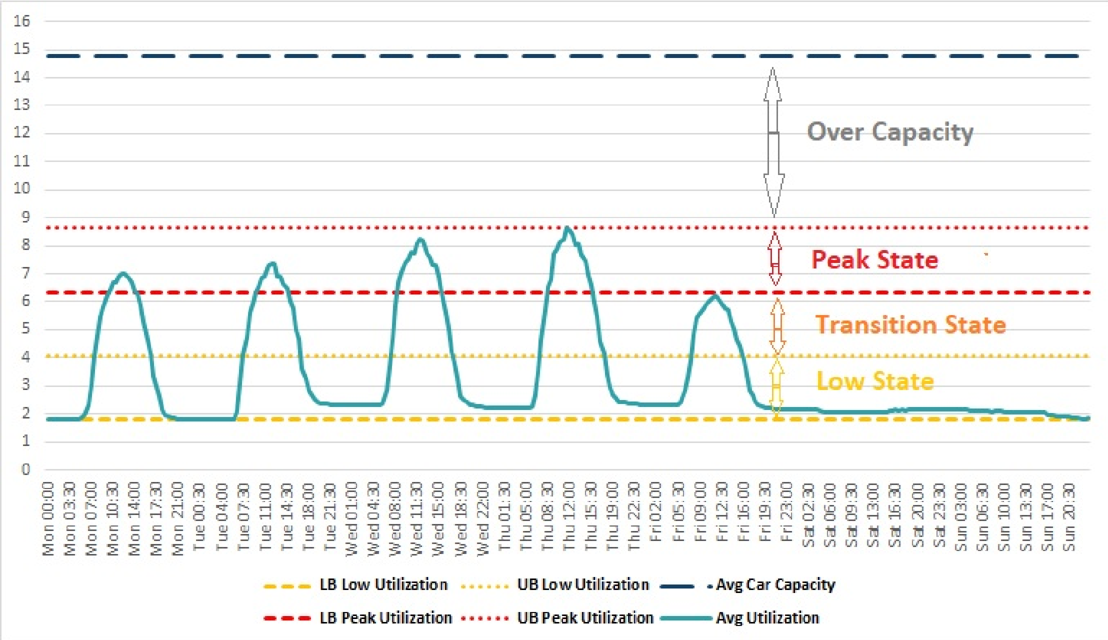

Figure 4.1: Utilization Flow throughout the Week in the Context of Utilization States

State	Range Lower Bound	Range Upper Bound
Peak State	6.35	8.64
Transition State	4.08	6.35
Low State	1.78	4.08

Additionally, to simplifying the analysis of the demand disparity in this section, the utilization states are used as reference points to explain the disparity (Section 4.2) and to adapt the toy problem (introduced in Section 1.2.1) to estimate the respective inefficiencies (Section 4.3). The toy problem adapted based on the utilization states returns in this version in Chapter 6.

4.1.2 Distribution over States

In Section 3.3 the flow of utilization of a car fleet of the Municipality of Amsterdam through the 30-minute time slots of a week is presented in Figure 3.7. Figure 4.1 sets the same utilization flow, which is based on Table A.7 in the Appendix, in the context of the three, above introduced, utilization states. Looking at this graphic and comparing the bounds of the states with the values in Table A.7 in the Appendix, it can be seen that the peak state is only entered from Monday till Thursday around noon. On Friday the average utilization reaches a high of 6.23 at 11:30 in the morning and thus stays slightly below a utilization of 6.35, the lower bound of the peak state. Furthermore, the utilization continuously stays in the low state throughout Saturday and Sunday.

The way they are constructed each of the three states covers one-third of the utilization value range seen throughout the week. However, the 336 time slots of the week (1 day has 48 30-minute time slots and the week has 7 days) are not as evenly distributed over the three states. How the aforementioned utilization flow throughout the week falls into the three states, based on the average utilization per time slot given by Table A.7 in the Appendix, can be seen in Figure 4.2. Exactly which time slots belong to which of the utilization states is indicated by Table A.8 in the Appendix. Based on the definition of the three utilization states and the previously calculated average utilization per time slot, it follows that the car fleet is in a low utilization state almost three-quarter of the week, 72 % of the week's time slots. A peak demand state is only reached during 15 % of the week's time slots. Furthermore, the average utilization value over the time slots belonging to the three states is calculated and added to the previous state overview:

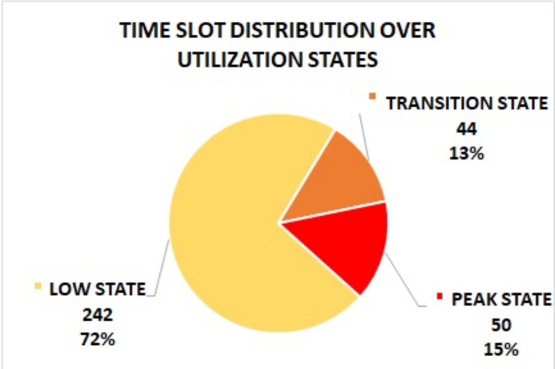

Figure 4.2: Distribution of the Week's Time Slots over the Utilization States

State	Range Lower Bound	Range Upper Bound	Avg. Utilization
Peak State	6.35	8.64	7.27
Transition State	4.08	6.35	5.34
Low State	1.78	4.08	2.24

4.2 Causes for Demand Disparity

The results of the previous section are now discussed under consideration of the knowledge about the use of a business internal car fleet through the employees. Attention is especially paid to the distribution of the time slots of the week over the defined utilization states and on which time slots the states are focused.

As discussed in Section 1.3.2 the car fleet of the Municipality of Amsterdam, analyzed in Section 3.3, is almost exclusively utilized for appointments during office hours from Monday to Friday by the Municipalities employees. Considering different start and end times per employee, work related utilization of cars could broadly be approximated to take place between 7:00 and 18:00. Looking at Tables A.7 and A.8 in the Appendix a rise of the utilization out of its low state can be seen, during the described 9-hour period on Monday to Friday. Assuming some employees start earlier than others, could explain an overlap in car utilization of these two groups around the middle of the day and therefore high utilization around noon. Furthermore, courtesy while making appointments with external parties might prevent appointments from being very early or very late during the office hours, which again would focus the car utilization to the middle of the day.

Assuming 9 hours per day from Monday to Friday to be the active utilization period, the utilization is left in a low state at least 15 hours (about 63 % of a day) on these days. Taking Monday to Friday together means the utilization is already about 45 % of the week in a low state. Since, the employees of the Municipality of Amsterdam normally do not work during the weekend, the utilization stays in the low state throughout Saturday and Sunday. This on its own makes up for two-sevens (about 29 %) of the whole week. Adding 45 % (out of office hours) and 29 % (weekend) together indicates that the utilization should be in a low state during 74 % of the week. Very close to the 72 % actually derived above.

Although Friday is a working day, the utilization apparently never enters a peak state on this day. This can be related to multiple causes. First of all, in many branches Friday is seen as an in-house day, where even employees who are on the road a lot throughout the week are more likely to stay at their own office, reducing the car utilization by these employees on Fridays. Furthermore, 4 days a week contracts are not uncommon and those with such a contract often do not work on Fridays to get the benefit of a long weekend, which might cause a slightly reduced staffing on Fridays. Given the case on hand, this second point is taken to a next level by the stereotypes about working weeks of municipalities having only 4 days in general.

4.3 Effects of Demand Disparity

To discuss the effects of demand disparity of business internal car fleet utilization, the toy problem from Section 1.2.1 is reintroduced (during the introduction of the toy problem some of the effects of demand disparity are actually already indicated). At first, areas affected by the demand disparity are identified and afterwards the extent of the effects is displayed through the toy problem.

4.3.1 Affected Areas

The effects of demand disparity of business internal car fleet utilization considered here have direct effects on the owning business. Less obvious effects on the respective business's environment are not considered at this point. As for the direct effects on the owning business, two areas are considered in alignment with WeGo's mission (see Section 1.1): The size of the fleet itself, which is driven by the peak demand state, and necessary parking space, which is driven by the low utilization state.

Fleet Size

The purpose of business internal car fleets is to offer mobility to (a part of) the employees and enable them to execute tasks which require mobility / a car. Therefore, the fleet size is determined by the peak demand during working hours of the business. In the upper part of Figure 4.1 a blue line is shown, which indicates the average capacity of the analyzed car fleet taken over the three-year review period. With an average capacity of 14.75 vehicles (see Section 3.2.2) the fleet size seems to be overly large, when compared to the upper bound of the utilization of 8.64 mentioned in Section 4.1. However, this upper bound is based on average values and the fleet size is not determined by these averages but by the extreme values. Table A.7 in the Appendix includes next to the average per time slot also the maximum utilization values per time slot, reached during the three-year review period, which include utilization values of up to 15 cars during a time slot. This puts the overcapacity indicated in Figure 4.1 in perspective. Furthermore, a fleet might include slightly more cars than the demand requires, e.g., for cases of maintenance. However, even if a fleet only included exactly the amount of cars needed to satisfy peak demand, Section 4.1 shows that the BICS only utilizes a majority of this amount of cars in a small percentage of the time (15 % of the week in the analyzed case). This small percentage drives the size of the fleet and therefore the respective ownership costs.

According to the Dutch National Institute for Family Finance Information, the monthly fixed costs (including lease, tax, maintenance, and insurance) for owning a car range from €149 to €342 depending on the car type [19]. Cars owned by businesses can be assumed to be in the upper price range. However, since businesses own multiple cars they might also get discounts on some cost categories. To have an easy to calculate value this research assumes, the monthly fixed costs for one vehicle of a business internal car fleet to be €300.

Parking Space

Although the parking space needed for BICS is related to the fleet size (and therefore the peak demand), it is mainly driven by the maximum amount of cars not in use at a certain moment in time and therefore driven by the low utilization state. If cars are in use they do not need a parking place. However, as is shown in Section 4.1 for a majority of the time (72 % of the week in the analyzed case) the cars of a BICS concept are not utilized and require a parking space. Therefore, the low utilization state determines, in theory, the parking space reserved by a business for its shared cars. It is in theory because some business might have one specific parking space assigned to one specific car. In this case the amount of parking spaces would be equal to the size of the fleet, without regards for the utilization.

Giving a value to parking space is less direct than the fixed costs for owning a car, since the parking space is normally part of a bigger facility. One way to determine the value of owning parking space is to consider the prices for public parking in the respective area. In the center of Amsterdam, where the reviewed car fleet has its parking spaces, prices vary from €1.50 to €5 per hour and from €10 to more than €21 for a whole day. This research assumes a value of €20 per day per parking space for this case.

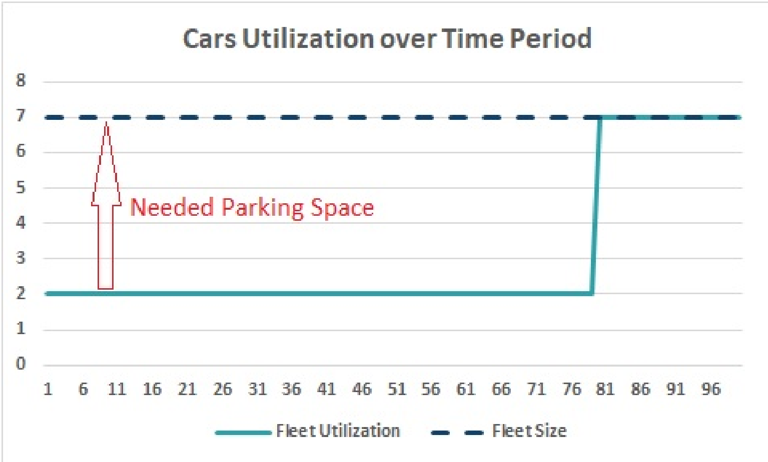

Figure 4.3: Toy Problem Example

4.3.2 Toy Problem Example

After discussing the effects of demand disparity for BICS, the findings of Section 4.1 are simplified in the style of the toy problem introduced in Section 1.2.1. The simplified version of the utilization results from the Municipality of Amsterdam are used to display the above discussed effects. For this purpose, the original toy problem, which evolves around a car fleet with 5 cars, is changed to resemble the case of the Municipality of Amsterdam fleet.

In Section 4.1 three utilization states are introduced. For the toy problem representation this is reduced to two states: a high state and a low state. The 13 % of time the utilization is in the transition state (see Figure 4.2) is equally divided over the other two states. Therefore, the simplified version is assumed to be in the low state 79 % of the time and the other 21 % of the time in the peak state. In the trend of the originally introduced toy problem the utilization during the two states is simplified such that during each state the utilization is always at one level. These utilization levels are derived from the average utilization values from the original utilization states (Section 4.1.2). This simplifies to a utilization of 7 cars for the peak state, based on an average utilization of 7.27 over the time slots belonging to the original state, and a utilization of 2 cars during the low state, based on an average utilization of 2.24 over the time slots belonging to the original state. Furthermore, the total size of the fleet is assumed to be the same as the utilization during the peak state. Figure 4.3 represents this simplified situation. In the simplification 5 of 7 cars (about 71 % of the fleet) are not utilized 79 % of the time and require a parking space. Time · volume, this equals 56 %, which are not utilized. Assuming a time period of one month and the effects mentioned before, the respective fixed costs of fleet ownership are €2,100 (€300 for 7 cars) and the value of the parking space is about €3,100 (€20 for 5 parking spaces over 31 days). This could be seen as a wasted investment of €1,176 (56 % of €2,100) fixed costs and loss of €2,449 (79 % of €3,100) potential revenues for parking space. Together this equals €3,625 each month, based on a fleet size of 7 cars.

4.4 Chapter Conclusion

This chapter discusses the inefficiencies resulting from the current use of BICS (presented in Chapter 3). It investigates the "Bottlenecks" and answers Sub-questions Q3, Q4 and Q4. Section 4.1 introduces utilization states and uses them to calculate the demand disparity throughout the week to answer Sub-questions Q3. Section 4.2 reflects on the knowledge about the usage of BICS (gained in Section 1.3.2) to understand the reasons for the demand disparity to answer Sub-questions Q4. Section 4.3 introduces an adapted version of the of problem to display inefficiencies caused by the demand disparity to answer Sub-questions Q5. The following chapter reintroduces the insights from the previously reviewed literature to discuss concepts which could help to solve the inefficiencies identified in this chapter. Furthermore, the next chapter introduces revenue management as a way to implement the concepts.

Chapter 5

Demand Control

The previous chapter identified the "Bottlenecks" - part of this research. This chapter forms a transition to the "Solutions" - part. Section 5.1 discusses how, in the literature mentioned, options to reduce travel demand (reviewed in Section 2.1) could be used for reducing peak demand of BICS. Section 5.2 on the other hand discusses options for reducing the disparity in BICS demand, by increasing demand in periods of low utilization. The discussion of options for demand control is followed by a modeling approach in Section 5.3.

5.1 Reducing Demand during Periods of Peak Demand

In Section 2.1 literature, related to the reduction of travel demand peaks, is reviewed. In the review two approaches can be distinguished, during the consideration of options for the reduction of demand during peak demand periods. This section discusses the options per approach. The first approach, discussed in Section 5.1.1, is to lower the demand in general. The second approach, discussed in Section 5.1.2, is to shift demand from the periods of peak demand to periods of lower utilization.

5.1.1 Diminish Demand

As mentioned before, cars in a BICS fleet are booked to satisfy the demand for business related traveling. The literature mentions a variety of measures to reduce car travel [30][32] and campaigns to support these [27]. Although, the mentioned studies consider car travel issues from a more general public perspective, some parts also apply to travel demand management in the context of BICS. A detailed discussion of the measures from Stradling et al. [32], relevant for this research due to internal influence-ability by businesses, can be found in Section B.1 in the Appendix. Additionally, in Section B.2 in the Appendix a four phased travel awareness campaign, based on Rose et al. [27] for a possible implementation in a BICS concept within WeGo's system, can be found. Since, WeGo facilitates the technology and services supporting the internal carsharing systems of multiple businesses, there might be an incentive for them to generate modular awareness campaigns, based on the functionalities of their system, which they could easily adapt to the requirements of their customers. Supported by a digital system and modular campaigns the work intensity could strongly be reduced. However, the intangible benefits (e.g., reputation and customer relations) might be bigger than the actual car use reduction. Given the in Section 1.2.6 described conflict for WeGo, in respect to helping customers to decrease their car fleets, this might be positive for them.

5.1.2 Shift Demand

As discussed in Section 4.2, the peak demand of BICS is restricted to specific periods of the week, the office hours (except for Fridays). Therefore, the possibilities for shifting bookings from periods of peak demand to periods of lower utilization seem limited, unless the restricting office hours can be designed less constraining. Literature suggest methods such as flex working, related to time and location, as promising methods to shift business related travel demand throughout the week. However, the flexibility of these practices stays limited, since the business-related travel often depends on the availability of multiple parties. Given the knowledge from Section 4.2 a different approach to compressed working weeks seem to have potential. Instead taking Fridays off in a four days week, a business could promote to take different days off, since the utilization of a car fleet seem to be lower on Fridays than on other days through the week. This might decrease the demand on other days in the week (where the demand is normally higher) and shift some demand to Friday. Furthermore, flexible start/end times of working hours might be able to slightly distribute the demand for car use more evenly throughout the day.

5.2 Promoting Demand in Periods of Low Utilization

Literature relevant for new demand sources for BICS is reviewed in Section 2.2. Such as for the reduction of demand during peak demand periods, two approaches can be distinguished during the consideration of options for the promotion of demand during periods of low utilization. The first approach, discussed in Section 5.2.1, is to promote utilization through employees using the cars for new functionalities. The second approach, discussed in Section 5.2.2, is to promote utilization through new / external users. The potential benefits for optimizing the utilization of BICS from promoting demand in periods of low utilization seem more promising, since the demand can be influenced by controlling the size of the user group and the pricing.

Literature indicates that public/private demand might be an opportunity to increase the utilization during periods where it is low in return for financial compensation (like users would also pay for ordinary carsharing). Furthermore, this extra demand might not even overlap with the peak business-related demand during office hours.

5.2.1 Internal

Given the stationary character of BICS in WeGo's system, a booking for a car can only be finished by returning the car to its home location (e.g., parking space at the business location), where it was picked up. Therefore, the option of commuting comes to mind for internally created demand (by employees) during periods of low utilization. When the cars are not used for business related traveling outside the office hours, they would be available for employees to be used for commuting. Literature indicates, when employees would have to pay for the non-business-related (as suggested before), an attractive payment model for the use for commuting would have to be figured out.

Besides using the cars for commuting, there might also be an interest by employees to use the cars for shorter periods for private trips outside the office hours. Especially for employees without a personal car, who occasionally need a car for recreational activities or have to transport heavy goods. The distance between work place and home of an employee might play a role, if a car is an interesting option for these demands.

In general, the already established trust and control between a business and its employees, should lower the barriers for allowing these extra demands.

5.2.2 External

Residents of a business's surrounding could be given access to use the business car fleet like other known carsharing concepts, during periods of low utilization. Literature indicates, the proximity of the cars to their homes would be convenient for these users and the demand they create for carsharing falls in the periods in which business fleets are currently underutilized. WeGo's system operates with closed user groups, where the owning business proposes the users which are allowed to access the cars. Furthermore, the system's modularity enables to determine the exact periods during which a user has access to specific cars. The business could determine which houses in its surrounding are offered access and could determine criteria to evaluate if a certain resident is allowed access. This procedure and the possibility to determine the pricing enable a business to increase (and decrease) the demand emerging from this origin.

5.3 Modeling

Section 5.1 and 5.2 indicate, allowing non-business-related bookings of employees and bookings of external users during periods of low utilization would be a promising option to reduce the level of demand disparity. Including the business-related bookings of employees, this would result in three different sources/categories for demand. Efficiently managing these demands presents an opportunity to improve utilization and additionally generate new revenue streams for a business. Models for these incentives can be found in revenue management, where the goal is to simultaneously maximize utilization and profit of a limited resource. A business is suited for revenue management given low variable costs, high fixed costs, perishable inventory, variable demand patterns, ability to forecast future demand and ability to segment demand [10]. Carsharing fulfills these six conditions.

In this section a revenue management-based modeling approach for the utilization optimization for BICS is discussed. Section 5.3.1 compares BICS to industries in which revenue management has successfully been applied, to gain insights for an application in BICS. These insights are used to introduce two concepts of revenue management models: Section 5.3.2 defines capacity control rules for BICS and Section 5.3.3 discusses price segmentation for BICS. Afterwards, the finger is pointed at a key success factor forecasting, in Section 5.3.4.

5.3.1 Comparison with Revenue Management Industries

Two industries have been picked to be compared with WeGo's BICS in respect to revenue management. As the origin of revenue management [34] and source of best practice, the airline industry is chosen. Furthermore, the hotel industry is chosen due to similarities in the nature of demand with carsharing.

Airline Industry

The problem of revenue management for the airline seat reservation industry can be split in three sub-problems: overbooking, discount allocation and traffic management [29]. In the following WeGo's BICS is compared to the airline industry in respect to these three sub-problems.

Overbooking: In the airline industry more seats for a flight are offered than there are in the respective airplane, to compensate for cancellations before the flight and passengers who do not show up [29]. Keys to making overbooking possible in the airline industry are that the specific seats are assigned only shortly before the flight (during the check-in) and a long planning horizon (flights are normally scheduled months in advance, which leaves more time for events).

In WeGo's BICS bookings are directly placed on cars, available for the desired booking period. Although this could be changed by notifying the user shortly before the planned booking period about which car is assigned, there is a relevant difference between a car fleet and seats on a specific airplane. While all seats on a specific airplane pursue the same journey at the same time, the bookings made for cars in a fleet vary, which adds complexity. Planned booking periods have different start times and durations. Furthermore, the user who has a booking does not have to start using the car at the beginning of the booking period but can do so at any point during the booking period, which makes identifying no-shows impossible until the booking period is fully passed. Therefore, bookings can also be canceled after the start of the booking period (as mentioned in Section 3.3). The 1,970 booking instances registered between January and August 2017 for the relevant cluster of the Municipality Amsterdam case data (see Section 3.2.2) include 406 canceled bookings. As Figure 5.1 illustrates, 25 % of these 406 bookings have been canceled after the start of the respective booking period. As mentioned the planning horizon in the airplane industry is longer than the planning horizon for BICS, which is probably related to the difference in travel distance, travel time and related costs. In the same data set as used for Figure 5.1, 1,957 bookings (the whole data set includes 1,970 entries, but 13 of these are missing the information about the booking creation) were placed in average 225 hours (9.4 days) before the start of the respective booking period. However, as Figure 5.2 indicates about 49 % of these booking instances were created at most 24 hours before the start of the respective booking period, which leaves less room to allow canceled bookings to be replaced by new bookings and less room for planners to react.

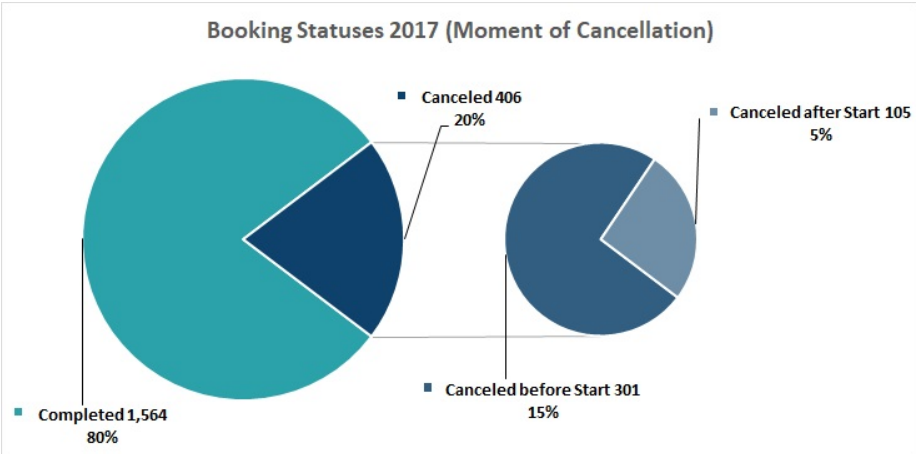

Figure 5.1: Frequency of cancellations (and when they occurred) in the booking data of the relevant cluster form the Municipality of Amsterdam from January till August 2017. Table A.6 in the Appendix includes the respective values.

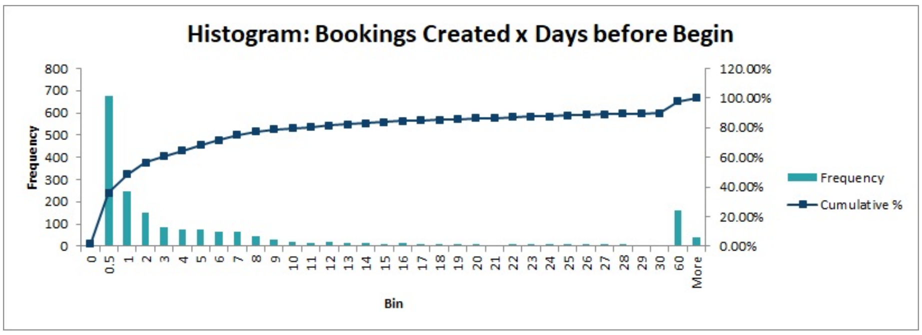

Figure 5.2: Histogram of the frequencies indicating how long in advance bookings are created, including a trendline of the respective cumulative percentages. Table A.9 in the Appendix can be reviewed for the specific bin sizes, respective frequencies, and cumulative percentages. This is based on the booking data of the relevant cluster form the Municipality of Amsterdam from January till August 2017

Discount allocation: In the airline industry fares for seats are changed (e.g., discounted) throughout the planning horizon of a flight to control demand [29]. The most basic allocation is between business and economy class fares, but there are infinitely more imaginable discounts based on services offered (e.g., extra luggage, consumption during the flight) and the moment of booking.

The proposed options to increase demand for BICS (Section 5.2) could be seen as different fare classes additionally to the existing business travel related demand. While in the airline industry the highest price gets the highest priority, this would be different for BICS. Here the main priority is to offer mobility for business related travel, which does not generate any (direct) revenues for the business, while the lower priority classes (i.e., employees private demand and external demand) could generate direct revenues. Carsharing does not include opportunities of extra services (assuming a homogeneous car fleet), which could be used to introduce further fares. However, discounts based on how long before the start of a booking period the booking is created might be possible. These could e.g., be used to stretch the planning horizon, by making it more attractive for users to schedule bookings further in advance of their start, which might generate more control for planners. Furthermore, access to booking periods could be allowed to certain classes at different times (e.g., one class can place a booking infinitely far before the wished booking period and a different class can place bookings only one week before the wished booking period).

Traffic management: Traffic management relates to the more complex networking scheduling in the airline industry, where flights are schedule in dependents on other (connection) flights. For revenue management this creates the challenge that some passengers use multiple flights on one journey, which influences the pricing and availability of seats on all involved flights [29]. This highly complex issues are not relevant in the context of WeGo's BICS, where a booking starts and end at the same location.

Hotel Industry

Revenue management in the hotel industry seems to some degree more comparable to carsharing. Features of revenue management strategies in the hotel industry concern the duration of bookings (i.e., number of nights), the start of bookings (e.g., which day of the week or which season) and how far in advance bookings are placed [4]. The features result in different discount rates for the same service (i.e., the same type of rooms). As indicated during the comparison between WeGo's BICS and revenue management in the airline industry, these are features which are also relevant for carsharing. Therefore, demand forecasting methods [35] and pricing strategies [10] for revenue management in the hotel industry, might be interesting for a revenue management implementation in BICS.

Besides the similarities between the two fields, there are also some differences. For one, as in the airline industry the planning horizon in the hotel industry is longer than for BICS. Some hotels have walk-in customers, but in general the planning horizon spans over months [4]. Furthermore, also in the hotel industry higher price means higher priority. Revenue management models in general would not allocate any capacity to a class, which represents 0 revenues.

Gained Insights for Revenue Management in WeGo's Business Internal Carsharing

Comparing BICS to revenue management in the airline and hotel industries revealed key features which have to be considered for an implementation of revenue management in BICS.

Going forward this research assumes that BICS prioritizes the three demand categories in a fixed order: business > internal private > external. This assumption stems from the main purpose of a business internal car fleet to offer mobility for its employees' business tasks and the existing relationship of trust and control with its employees in contrast to novel external users. This creates an uncommon situation for revenue management, where the highest priority segment (business related demand) is not priced and does not generate any (direct) revenues. In revenue management price determines priority and in addition sometimes with an increase in price a decrease in volume is assumed [34]. While prioritizing between the three categories is not price driven, a price driven segmentation within the categories could be possible (with exception of the business-related demand category). As mentioned before, the demand source (user pool) for BICS in WeGo's system is limited and users have to be allowed to join the system by the business. During this procedure different fees (in respect to time and reason for usage) and availability restrictions can be assigned to a new user.

In industries such as the airline industry, revenue management algorithms are established technologies, which operate automatically. However, they do not execute changes in the booking system automatically. The algorithms generate advice on a periodic basis, which are interpreted by human revenue managers / planners, who use the data to execute changes in the booking system [34]. This iterative procedure is possible due to a relatively long stretched planning horizon. With carsharing, trips are shorter (distance and time), which enables a majority of the demand to occurs relatively spontaneous. This difference limits the planning horizon and reaction capacity. Therefore, demand forecasting and proactive decision making become even more important.

Assuming that all cars in a business internal car fleet fulfill the same functionality, the offered service is homogeneous. There are no opportunities to extend the service by including consumption or a more luxurious product. Therefore, price segmentation in BICS is restricted to the timing of bookings (i.e., when is the start of the desired booking, what is the duration of the desired booking and how far in advance is the booking generated).

Revenue management involves advanced algorithms and technology. The airline industry was accustomed to these tools long before revenue management was integrated. The complexity of the industry drove the knowledge from early on in fields such as operations research to generate advanced scheduling methods. This experience was a key factor for the successful integration of revenue management [34]. Pubic Carsharing and BICS are relatively young industries. Although, technology plays a central role in these industries, they and most of the involved businesses seem less geared to be introduced to revenue management. It took a long time for the airline industry to reach the current heights of revenue management. This should be realized when considering the complexity of a first revenue management introduction to BICS.

5.3.2 Capacity Control Rules

Notational Overview

The capacity control rules are in the following expressed in the form of formulas. The sets, parameters and variables used in these formulas are defined here and reintroduced later in this part.

Sets:		
Demand categories	$i \in \{\alpha, \beta, \gamma\}$	,
Time slots	$t \in T$	T being the planning horizon;
Parameters:		
Total capacity	$C \in \mathbb{Z}^*$	,
Demand expectation on t from i	$d_{it} \in \mathbb{Z}^*$	for $i \in \{\alpha, \beta, \gamma\}$ and $t \in T$,
Actual demand on t from i	$D_{it} \in \mathbb{Z}^*$	for $i \in \{\alpha, \beta, \gamma\}$ and $t \in T$,
Capacity on t occupied by i	$C_{it} \in \mathbb{Z}^*$	for $i \in \{\alpha, \beta, \gamma\}$ and $t \in T$,
Set of low demand time slots	$L \subset T$	,
Set of high demand time slots	$H \subset T$	;
Variables:		
Booking limit on t for i	$b_{it} \in [0, C]$	for $i \in \{\alpha, \beta, \gamma\}$ and $t \in T$,
Protection level on t for i	$y_{it} \in [0, C]$	for $i \in \{\alpha, \beta, \gamma\}$ and $t \in T$,
Booking period	$B \subseteq T$	.

Earlier in this section the concept of three demand categories is introduced: business related demand, private internal demand, and external demand. In the following mathematical formulas are used to describe the revenue management models. In these formulas the demand categories are referred to in respective order by α, β, and γ. As mentioned before, the prioritization of these categories does not align with their profitability. Therefore, capacity control rules are defined to protect the necessary capacity for high priority (low profit) categories, which common revenue management models would otherwise neglect. When these rules are defined the pricing part of revenue management is discussed in the following section.

Before combining all three demand categories, at first a capacity control rule model for the two categories with the highest priority is introduced. To the already active business-related demand category, the demand category of private use by internal employees is added.

Capacity Control Rule for Business Internal Carsharing with 2 Demand Categories (Business and Internal Private)

As discussed in the previous section, the business-related demand is necessary to support the core business. Employees do not pay for the bookings they make for the business. Therefore, this demand does not represent direct revenues. However, the demand supports the core business and generates revenue in an indirect manner. It is assumed, that businesses do not mind which value could be traced back to the business bookings. Even if a model considers lower revenue potential for the business demand, it should always acknowledge a higher priority for the business demand, than for the internal private (or external) demand. Therefore, the part of the total capacity (C), which is expected to be needed to satisfy the business-related demand, should be protected from the internal private demand. A fundamental revenue management concept, booking limits and protection levels, [34] can be used for the described discrimination. While the booking limit indicates the maximum capacity a category can demand, the protection level of a category indicates how much capacity is reserved for that category and all categories with higher priority, thus protected from lower priority categories. In the described prioritization situation, the booking limits and protection levels are determined as follows:

$$b_{\alpha t} = C \qquad \forall\ t \in T \tag{5.1}$$
$$b_{\beta t} = max\{C - d_{\alpha t}, 0\} \qquad \forall\ t \in T \tag{5.2}$$
$$y_{\alpha t} = min\{d_{\alpha t}, C\} \qquad \forall\ t \in T \tag{5.3}$$
$$y_{\beta t} = C \qquad \forall\ t \in T. \tag{5.4}$$

Equation 5.1 defines the booking limit for the business demand ($b_{\alpha t}$) at any time slot (t) in the planning horizon (T) to be equal to the total car capacity (C). Equation 5.2 defines the booking limit for the internal private demand ($b_{\beta t}$) at any time slot in the planning horizon to be equal to the expected free capacity, left after subtracting the expected business demand ($d_{\alpha t}$) from the total capacity, or 0 if the expected business demand exceeds the capacity. Equation 5.3 defines the protection level for the business demand ($y_{\alpha t}$) at any time slot in the planning horizon to be equal to its expected demand, or the total capacity when the expected demand exceeds the capacity. Equation 5.4 defines the protection level for the internal private demand ($y_{\beta t}$) at any time slot in the planning horizon to be equal to the total capacity (since there is no lower priority category, this protection level is trivial).

To give an example for the capacity control rules for a case with two demand categories (business and private internal) the toy problem from Figure 4.3 is used. Since the booking limits and protection levels are two interchangeable ways to express the same capacity control rules (as can easily be seen $y_{\alpha t} = C - b_{\beta t}\ \forall\ t \in T$) this example focuses on the booking limits. The toy problem considers 7 cars ($C = b_{\alpha t} = 7$). Its time slots (the planning horizon) are divided into two sets, the time slots belonging to the low demand state $L \subset T$ and those belonging to the high demand state $H \subset T$ (where $L \cap H = \emptyset \wedge L \cup H = T$). For the demand expectations of the business demand, the same levels as for the states in Figure 4.3 are considered. For all time slots belonging to the low state a business demand of 2 cars is expected and for all time slots belonging to the high state a business demand of 7 cars is expected (i.e., $d_{\alpha t} = \left\{ \begin{array}{ll} 2 & \forall\ t \in L \\ 7 & \forall\ t \in H \end{array} \right.$). Respectively, the booking limits for the internal private demand restrict the amount of coincidental bookings from the private internal category to 5 during the time slots of the low state and to none during the high state (i.e., $b_{\beta t} = \left\{ \begin{array}{ll} 5 & \forall\ t \in L \\ 0 & \forall\ t \in H \end{array} \right.$). This is represented in Figure 5.3.

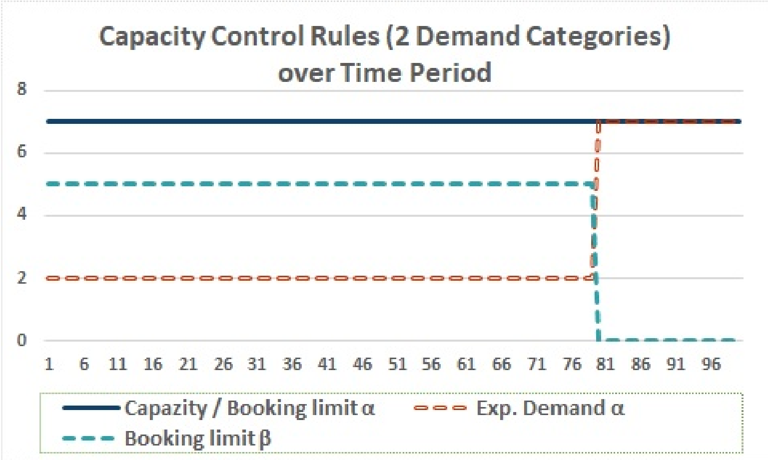

Figure 5.3: Booking Limit Example for Toy Problem Case with 2 Demand Categories

Let $B \subseteq T$ be the time slots covered by the period of a requested booking and let C_{it} be the capacity occupied by category $i \in \{\alpha, \beta, \gamma\}$ on time slot $t \in T$ at the moment of the request. The defined rules always accept a business booking request (category α), as long as there is free capacity on all time slots covered by the booking (i.e., when $\sum_i C_{it} < 7 \; \forall \; t \in B$). On the other hand an internal private booking request is only accepted, when the capacity already occupied by this category is smaller than its specific booking limit on every time slot covered by the booking request (i.e., when no time slots covered by the booking period belong to the high state period ($B \cap H = \emptyset$) and $C_{\beta t} < 5 \; \forall \; t \in B$) and if the total capacity is not already occupied (i.e., when $\sum_i C_{it} < 7 \; \forall \; t \in B$).

Capacity Control Rule for Business Internal Carsharing with 3 Demand Categories (Adding External)

When the third demand category, demand from external users, is added to the model two options can be considered. A business can prioritize the demand stemming from the private use of its internal employees over the external demand (Equation 5.5-5.10), or it could choose to let both categories compete for the same capacity since both categories are (partly) financially orientated (Equation 5.11-5.14). In both options, the business-related demand should stay protected according to its priority. Again, booking limits and protection levels are used to model the desired capacity allocation. In the following the two options are discussed separately.

Prioritizing can be used when a company has a clear preference for the private use of its cars by employees, above the demand of external users. In this case the previously defined rules for two demand categories are extended by another layer. The literature talks about a nesting of the booking limits and protection levels according to the prioritization [34]. Integrating a nesting into the previous rules results in the following rules:

$$b_{\alpha t} = C \qquad \forall \; t \in T \tag{5.5}$$
$$b_{\beta t} = max\{C - d_{\alpha t}, 0\} \qquad \forall \; t \in T \tag{5.6}$$
$$b_{\gamma t} = max\{C - d_{\alpha t} - d_{\beta t}, 0\} \qquad \forall \; t \in T \tag{5.7}$$
$$y_{\alpha t} = min\{d_{\alpha t}, C\} \qquad \forall \; t \in T \tag{5.8}$$
$$y_{\beta t} = min\{d_{\alpha t} + d_{\beta t}, C\} \qquad \forall \; t \in T \tag{5.9}$$
$$y_{\gamma t} = C \qquad \forall \; t \in T. \tag{5.10}$$

Equations 5.5, 5.6 and 5.8 are equivalent to Equations 5.1, 5.2 and 5.3 from the previous rules, since the addition of a lower priority category does not influence the booking limits for the business ($b_{\alpha t}$) and internal private demand ($b_{\beta t}$) and the protection level of the business demand ($y_{\alpha t}$). Equation 5.7 defines the booking limit for the external demand ($b_{\gamma t}$) at any time slot in the planning horizon to be

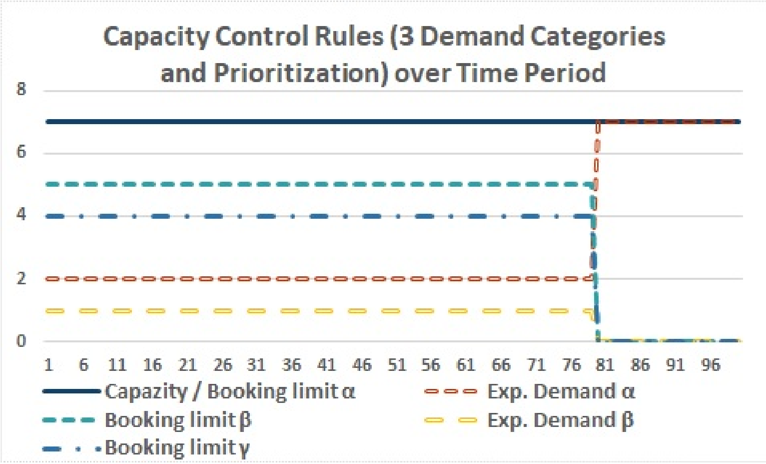

Figure 5.4: Booking Limit Example for Toy Problem Case with 3 Demand Categories and clear Prioritization

equal to the expected free capacity left after subtracting the expected business demand ($d_{\alpha t}$) and the expected private internal demand ($d_{\beta t}$) from the total capacity, or 0 if the expected demands exceed the capacity. Equation 5.9 defines the protection level for the private internal demand ($y_{\beta t}$) at any time slot in the planning horizon to be equal to its expected demand plus the expected demand of all high priority categories, or the total capacity when the expected demands exceed the capacity. Equation 5.10 defines the protection level for the external demand ($y_{\gamma t}$) at any time slot in the planning horizon to be equal to the total capacity (since there is no lower priority category, this protection level is trivial).

To give an example for the capacity rules of a situation with three demand categories and clear prioritization, the toy problem case from Figure 5.3 is extended with an expected demand for the private internal category and a booking limit for the external category, based on Equation 5.7. As in Figure 5.3 the booking limit for the private internal category is 0 during the time slots of the high state and 5 during the time slots of the low state. Furthermore, the employees can be expected to be working during the high state (which represents their office hours). Since information about their demand during the low state time slots is not available, this research conservatively assumes the demand to be 1 in average when they are not working. Therefore, the expected demand from the private internal category is assumed to be 0 during the high state time slots and 1 during the low state time slots (i.e., $d_{\beta t} = \left\{ \begin{array}{ll} 1 & \forall\ t \in L \\ 0 & \forall\ t \in H \end{array} \right)$. The booking limit for the external category, now follows from Equation 5.7. During the high state time slots it is 0, since the whole capacity is protected for the business category, and during the low state time slots it is 4, since 2 cars are protected for the business category and 1 additional car is protected for the private internal category (i.e., $b_{\gamma t} = \left\{ \begin{array}{ll} 4 & \forall\ t \in L \\ 0 & \forall\ t \in H \end{array} \right)$. This is represented in Figure 5.4.

The defined rules with the nested booking limits and protection levels work similar to the rules for only two demand categories. Booking requests from the business and private internal categories are treated exactly the same way. An external booking request (category γ) is only accepted, when the capacity already occupied by this category is smaller than its specific booking limit on every time slot covered by the booking request (i.e., when no time slots covered by the booking period belong to the high state period ($B \cap H = \emptyset$) and $C_{\gamma t} < 4\ \forall\ t \in B$) and if the total capacity is not already occupied (i.e., when $\sum_i C_{it} < 7\ \forall\ t \in B$).

Theft Nesting is a complementary strategy for nested capacity control rules, which can be considered for adjusting protection levels when demand of high priority categories turns out to be higher than the expectation. Assuming a situation where the demand of the highest priority category

(α) turns out to be higher than the expectation ($d_{\alpha t}$), which is used to set the booking limits and protection levels. Let the actual demand from the business category be $D_{\alpha t}$. If the requests from this category arrive before requests from all other categories they will all be accepted (according to the rules). In this case not enough capacity is protected for category β from lower priority categories (i.e., $D_{\alpha t} + d_{\beta t} > y_{\beta t}$), since the higher priority category α 'stole' from the capacity protected for β. Unless the predefined booking limit for category γ and protection level for category β are adjusted, requests from the lowest priority category could be accepted and cause later incoming requests from category β to be rejected. When theft nesting is applied the booking limits and protection levels would be adapted to such situations during the planning horizon.

Competing can be used when a company wants to extend the BICS in a more financially orientated manner. While still protecting the necessary capacity for business related demands, no capacity is protected for the private internal demand. The private internal and external category have access to the same capacity, which is left over from the highest priority category. When demand from the two competing categories is seen equal and the rules stay basically the same as for the model with only two demand categories:

$$b_{\alpha t} = C \qquad \forall\ t \in T \tag{5.11}$$

$$b_{\beta t} = b_{\gamma t} = max\{C - d_{\alpha t}, 0\} \qquad \forall\ t \in T \tag{5.12}$$

$$y_{\alpha t} = min\{d_{\alpha t}, C\} \qquad \forall\ t \in T \tag{5.13}$$

$$y_{\beta t} = y_{\gamma t} = C \qquad \forall\ t \in T. \tag{5.14}$$

Equation 5.11 defines the booking limit for the business demand ($b_{\alpha t}$) at any time slot (t) in the planning horizon (T) to be equal to the total car capacity (C). Equation 5.12 defines the booking limits for the internal private demand ($b_{\beta t}$) and external demand ($b_{\gamma t}$) at any time slot in the planning horizon to be equal to the expected free capacity, left after subtracting the expected business demand ($d_{\alpha t}$) from the total capacity, or 0 if the expected business demand exceeds the capacity. Equation 5.13 defines the protection level for the business demand ($y_{\alpha t}$) at any time slot in the planning horizon to be equal to its expected demand, or the total capacity when the expected demand exceeds the capacity. Equation 5.14 defines the protection level for the internal private demand ($y_{\beta t}$) and external demand ($y_{\gamma t}$) at any time slot in the planning horizon to be equal to the total capacity (since there is no lower priority category, this protection level is trivial).

An example for the capacity rules of a situation with three demand categories of which the lower two are competing for the same capacity is basically the same as the toy problem case from Figure 5.3. For the additional external demand basically, the same booking limit as for the private internal demand from this example applies.

With these rules again, a business booking request (category α) is always accepted, as long as there is free capacity on all time slots covered by the booking (i.e., when $\sum_i C_{it} < 7\ \forall\ t \in B$). However, for accepting a private internal or external booking request, the exact same control values are used. These requests are seen as completely equal (although the price might be different, as is discussed in the following section). A request from one of the two categories (β or γ) is accepted, when there is still free capacity, besides the capacity protected for the business-related demand (i.e., when $B \cap H = \emptyset$ and $C_{\beta t} + C_{\gamma t} < 5\ \forall\ t \in B$) and if the total capacity is not already occupied (i.e., when $\sum_i C_{it} < 7$).

5.3.3 Price Segmentation

Notational Overview

As for the capacity control rules some mathematical expressions are used to describe the price segmentation. Most of the notations introduced in the beginning of Section 5.3.2 are also used in this part. However, there are a few additions:

Time difference between request and booking start	$\Delta \geqslant 0$,
Price quotation function requested Δ in advance from i for one t with C_{it} occupied	$p(i, t, C_{it}, \Delta) \geqslant 0$,
Price quotation function from i for the whole period B	$P_{iB} \geqslant 0$.

The defined capacity control rules determine whether or not a booking request from a certain category is accepted. For the case in which capacity control rules are in favor of the request, a respective price has to be quoted for the booking. Let P_{iB} be the price quotation for a booking request from category $i \in \{\alpha, \beta, \gamma\}$ with period $B \subseteq T$. In revenue management theory this quotation is flexible and should be set in a way, which maximizes the total profit gained with the available capacity. Depending on the complexity of the product, quotations can depend on a whole network of resources [34]. A price quotation in WeGo's BICS for booking a car at a specific time slot, might depend on:

- the requesting category,
- the specific time slot (i.e., the expected demand for it),
- the capacity still available for the requesting category,
- and how far in advance the booking is requested (represented by Δ).

This makes the price quotation for a booking request of a specific time slot a function depending on four variables: $p(i, t, C_{it}, \Delta)$. While determining the exact dynamics of this function does not belong to the scope of this research, the general idea of the four variables is discussed. Afterwards, the price quotation is extended to bookings of multiple time slots and the inclusion of penalties to prevent or compensate cancellations is discussed.

Requesting Category i

Besides their different treatment regarding the capacity control, the three demand categories might also be treated differently when it comes to pricing. While employees do not pay for bookings of the business demand (category α), they would most likely be quoted for private bookings (category β). However, there might be an argument why they could be quoted a lower price than an external user (category γ) for the same booking. Category β might get a discount on the full fair (which is quoted to category γ), due to their established relationship with the company, which might offer the access as fringe benefit.

As utilization can be influenced in timing and volume by the right pricing strategy, a company could also introduce a virtual currency, which employees could use to "pay" for their business-related bookings. In this case a separate pricing strategy would be required for every category $i \in \{\alpha, \beta, \gamma\}$, since every category probably shows different behavior towards the same pricing strategies and the company has different objectives for the categories. These strategies might be expressed in one pricing table per category, with dimensions according to the included factors (i.e., t, C_{it}, Δ).

Time Slot t

When pricing a resource, the correlation with the demand should be considered. While many factors influence the exact willingness of users to except a price, the general assumption is a negative correlation between the demand for a resource and its price [38] (as indicated by Figure 5.5). However, not every time slot has the same utility for the user and therefore for the owning business. Assuming a constant price for all time slots, the expected demand for every time slot would be different. Some time slots are more popular and have higher expected demand. When the goal is to maximize profit and utilization of the resources (time slots of the limited amount of cars), time slots with a higher expected demand (under constant price) could be priced higher, while still achieving same utilization values. Therefore, the pricing of a time slot should be positively correlated to its expected (price independent) demand. An example for this relationship is shown in Figure 5.6, where the price starts at a certain minimum (related to profitability) and converges towards a maximum, above which no customer would be willing to book.

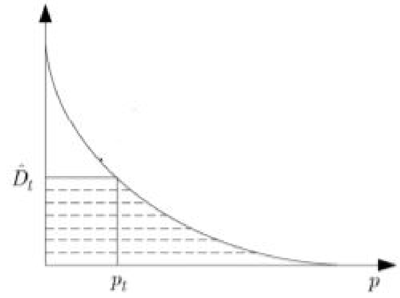

Figure 5.5: Results from a Statistical Demand-Price Model from [38]. *The graph shows the demand D_t related to a price P_t at time t.*

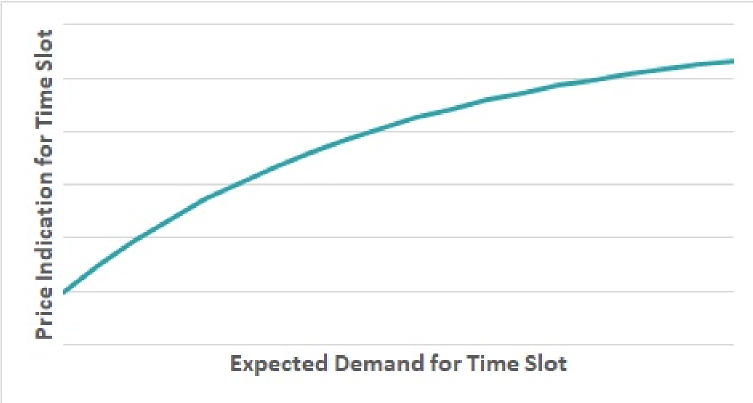

Figure 5.6: Price Indication for a Time Slot in respect to its Expected Demand

Available Capacity for Requesting Category C_{it}

The capacity control rules (Section 5.3.2) state how much capacity is available for a specific demand category during each time slot in the planning horizon. During the planning horizon the scarcity for the categories increases, when users place bookings which are subtracted from the available capacity for the category during the involved time slots. As an example, two situations can be compared. Both assume a system with three demand categories ($i \in \{\alpha, \beta, \gamma\}$ as introduced before) and capacity rules which model a clear prioritization (as described by Equation 5.5-5.10).

Scenario A assumes a booking request from category γ (external demand), which involves a specific time slot t_1. The booking limit (i.e., available capacity) on this time slot for category γ is assumed to be 5 (i.e., $b_{\gamma t_1} = 5$). Furthermore, at the moment the request is done none of the three categories has booked capacity at time slot t_1 (i.e., $C_{it_1} = 0 \; \forall \; i \in \{\alpha, \beta, \gamma\}$).

Scenario B also assumes a booking request from category γ, which involves the same time slot t_1, with the same booking limit. However, in this situation 4 booking requests from category γ, which involve time slot t_1, have already been accepted (i.e., $C_{\gamma t_1} = 4$). Furthermore, it is assumed that the higher priority categories have not exceeded the capacity protected for them. Therefore, there is capacity left for one more booking form category γ, involving time slot t_1 (i.e., $b_{\gamma t_1} - C_{\gamma t_1} = 1$).

In both scenarios, according to the capacity control rules, the booking request could be accepted. However, it should be clear that due to the difference in scarcity, the same time slot has a different utility in the two scenarios. Only if the expected demand left decreases (the excepted requests are subtracted from the expected demand) as fast to neglect the increase in scarcity the utility stays the same. Assuming the scarcity increases faster, a positive correlation between the amount of already accepted bookings on a specific time slot(C_{it}) and its price can be argued. An example for this rela-

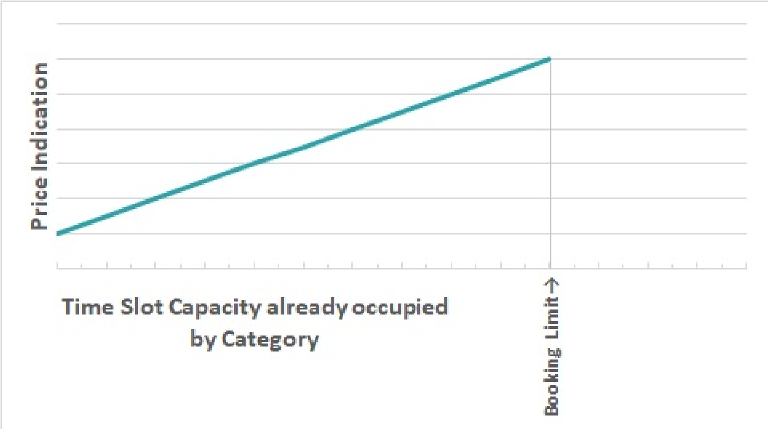

Figure 5.7: Price Indication for a Time Slot in respect to the Amount of already accepted Bookings

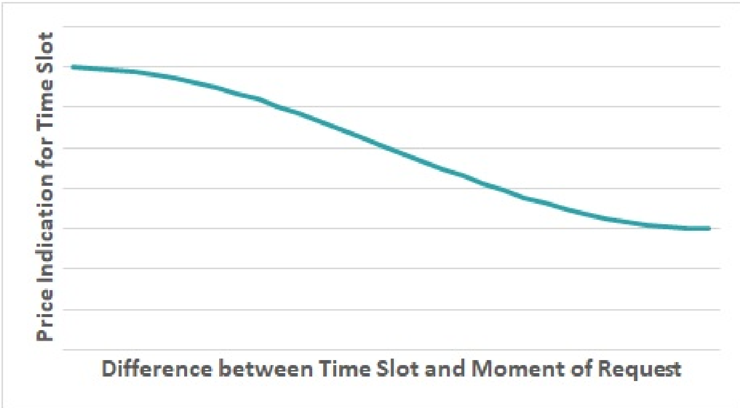

Figure 5.8: Price Indication for a Time Slot in respect to the Difference in Time to the Moment of Request

tionship is shown in Figure 5.7, where the price starts at a certain minimum (related to profitability) and grows towards a maximum (the slope of the relationship might not be linear), which is reached when the occupation of a category reaches its booking limit for the specific time slot. As for Figure 5.6 this maximum should be related to a benchmark, customers are willing to pay.

Request Moment Δ

How the exact moment of a request (how far in advance of the start of the booking period) influences the pricing should be related to two issues. The first issue is: when the planning horizon approaches a time slot, it becomes less likely that requests will be placed, which include this time slot. Therefore, there is an incentive to lower the price for a time slot when it comes closer, given the time slot still has free capacity which is desired to be filled. The second issue is: the desire of receiving requests early in the planning horizon, to allow the planners more time to react on events. Therefore, there is an incentive to increase the price for a time slot when it comes closer. Since carsharing bookings are requested comparably shortly before their start time, which puts the focus on proactive revenue management methods (Section 5.3.1), the incentive might be stronger for increasing the price of a time slot when it comes closer. Due to the price incentive customers might start to request bookings earlier in advance, which would give planners more time to react on events (i.e., adapt prices when forecasts seem to be off). An example for this relationship is shown in Figure 5.8, where the price has a certain maximum (related to the price sensitivity of customers) if the booking would be requested directly on the desired time slot and decreases towards a minimum (related to profitability) when the time slot is requested further in advance.

Quoting Bookings of multiple Time Slots

When a time slot is seen as a resource, bookings often involve a network of resources due to their duration covering multiple time slots. In a simplistic model the price quotation for a booking of multiple time slots would therefore be the sum of the quotations for all involved time slots:

$$P_{iB} = \sum_{t \in B} p(i, t, C_{it}, \Delta). \tag{5.15}$$

In a more complex model, interconnection of the network might have an additional influence on the price quotation. A booking might require a minimum and/or maximum of time slots to be accepted/quoted. Furthermore, the combination of certain bookings might result in a price discount or premium.

Cancellation Penalties

When a booking is accepted and then canceled, there is a risk that the capacity on the time slots involved in the booking will not be utilized. As closer the moment of cancellation comes to the start of the booking period (or even happens during the booking period) this risk increases. Depending on this risk, penalties could be included to compensate for the risk or even lower the probability of cancellations. Without penalties customers do not have to pay the price quoted for the canceled booking. Penalties would require the customers to still pay a part of the quoted price or even the whole price, depending on when the booking is canceled. In theory penalties could be calculated by subtracting the expected revenues (i.e., probability that the involved time slots get booked after the moment of cancellation $\cdot$ the related expected price quotations for the time slots) from the price quotation of the canceled booking. In practice penalties are often scaled in a way that customers do not pay a penalty when they cancel a certain time x before the start of the booking, pay a certain percentage of the price quotation when they cancel between time x and time y before the start of the booking, and pay the whole price quotation when they cancel after time y before the start.

5.3.4 Forecasting

Assuming that the short planning horizon of carsharing bookings requires a focus on proactive revenue management methods, robust forecasts are important for these methods. The booking limits and protection levels of the defined capacity control rules have to be set in advance, based on demand forecasts. If these forecasts are inaccurate there might not be enough capacity reserved for high priority demand or a lot capacity could stay unutilized. Some revenue management methods can be proactively modeled to be reactive to some degree, like the discussed theft nesting (see Section 5.3.2). However, most of them only work in certain scenarios. Theft nesting for example is ineffective, when requests from low priority categories arrives first. Due to the short planning horizon, a feasible approach for BICS seems to use forecasting to periodically update predefined booking limits, protection levels and pricing tables for the three categories.

According to Weatherford and Kimes [35] exponential smoothing is one of the methods which seems to deliver robust forecasts in the hotel industry. Due to the aforementioned similarities between the hotel industry and carsharing, robust forecasting methods form the hotel industry might be interesting to look into for carsharing.

5.4 Chapter Conclusion

This chapter is dedicated to beginning the process of finding solutions for the situation established in previous chapters. Section 5.1 reflects on previously reviewed literature to identify options for reducing peak demand of BICS to answer Sub-question Q6. Section 5.2 reflects on previously reviewed literature to identify options for increasing demand of low utilization periods of BICS to answer Sub-question Q7. Section 5.3 introduces revenue management to see how the options for demand control could be modeled and implemented to answer Sub-question Q8. Chapter 7 comes back to this sub-question, with recommendations regarding these options. The following chapter considers the feasibility of the concepts proposed in this chapter. It shows the respective benefits, but also discusses thresholds.

Chapter 6

Benefits & Thresholds

Chapter 5 discusses ways to reduce the inefficiencies of BICS and how these could be implemented with the help of revenue management. This chapter focuses on possible results from such an implementation. Section 6.1 shows possible positive results regarding three involved topics, based on a comparison with Section 4.3 and the benefits found in literature (Section 2.3). Section 6.2 discusses which thresholds might exist in respect to the two major novelties of a possible implementation. Section 6.3 then investigates ways to solve the mentioned thresholds.

6.1 Benefits

The benefits of allowing employees to book the cars of a business for private use and also allow external usage of residents with the help of the in Section 5.3 introduced revenue management concepts, is discussed in three parts. At first the internal benefits for the business owning the car fleet are investigated, through a comparison with the inefficiencies discussed in Section 4.3 (Section 6.1.1). The scope is extended and the external benefits for the environment (of the business) are discussed in Section 6.1.2. The benefits are brought full circle in Section 6.1.3, by looking into possible benefits for WeGo the facilitator of the involved carsharing technology (and party to which this research is addressed).

6.1.1 Benefits for Businesses

Chapter 5 indicates that data is missing to exactly evaluate the effects of discussed measures to low peak demand, increase utilization and how to set pricing. Therefore, the following discussion of benefits for the owning business is based on a few assumptions and brought down to a per unit base, to give an indication of the possible benefits. The earlier introduced toy problem (Section 4.3.2) is reintroduced to graphically support the discussion.

Assumptions

- No peak demand reductions through travel management measures (Section 5.1).
- Private internal and external demand is allowed in periods where demand is not in the peak state (i.e., working hours) (Section 4.1).
- In periods where private internal and external demand is allowed, in average one car is occupied per demand source (Section 5.2)
- Profits from external demand are €10 per hour (based on the range of hourly carsharing prices [26])
- Profits from private internal demand are €8 per hour (based on the same value as for external demand but reduced by a 20 % discount).
- The assumed profits consider that the price quoted to the users would be higher such that respective costs like fuel for driven km are compensated.

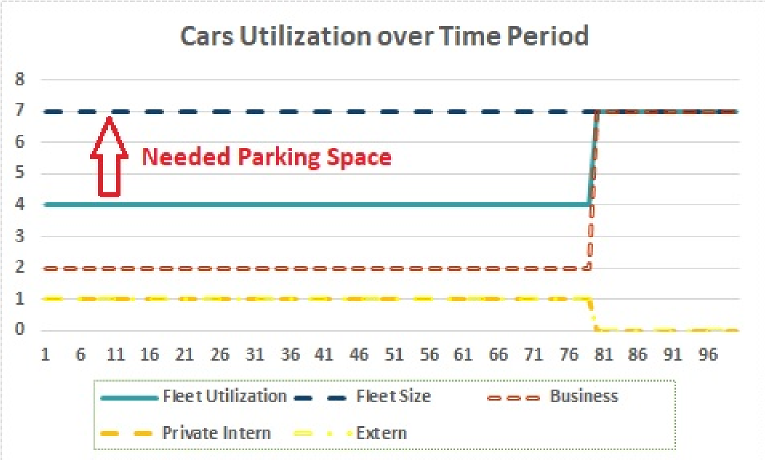

Figure 6.1: Toy Problem Example with Increased Demand during Low Utilization Period

Financial Implications

The previous toy problem in Figure 4.3 from Section 4.3 considers two demand states a low demand state, in which the car fleet stays 79 % of the time, and a high/peak demand state, which is reached during 21 % of the time. Based on the findings of the utilization of the relevant cluster from the Municipality of Amsterdam (Section 3.3), the business-related bookings utilize 7 cars (the full capacity of the toy problem fleet) during the high state and 2 cars during the low state. Assuming the addition of the new demand sources during the low state raises the utilization in this period by 2 cars (1 due to private internal bookings and 1 for external booking), the utilization during the low state changes to 4 cars. Figure 6.1 illustrates the changed situation.

Under these assumptions, only 3 cars (43 % of the fleet) are not utilized during the low state (79 % of the time) instead of 5 cars (71 % of the fleet) as in the case where only business-related demand is allowed. Considering time and volume, due to the new demand, only 34 % stay not utilized instead of 56 %. With the monthly fixed costs for a fleet of 7 cars being €2,100 (Section 4.3) the monthly investment waste is reduced from €1,176 (56 %) to €714 (34 %), which is a reduction of €462.

The theoretically required parking space is reduced from 5 to 3 spaces. Considering a monthly value of €620 per parking space (Section 4.3), the loss of potential revenues for the parking space during the low utilization period is reduced from €2,449 (5 spaces of €620 during 79 % of the time) to about €1,469 (3 spaces of €620 during 79 % of the time), which is a reduction of €391. On the other hand, the potential revenues during the high demand period, where the spaces could be rented out to other cars, reduce from €651 (5 spaces of €620 during 21 % of the time) to €391 (3 spaces of €620 during 21 % of the time), which means a reduction in potential revenues of €260. Holding these two values against each other, results in a reduction of loss of potential revenues of €131 euro each month.

Besides the reduction of theoretical losses, introducing the new demand sources generates profits form the use of private internal and external bookings. Considering a month has 720 hours, the demand is in the low state 569 hours (79 %) each month. Assuming that for each hour €8 are generated from the private internal demand and €10 from the external demand, means €18 extra profit for each hour the demand is in the low state. Integrating the two demand sources thus generates €10,242 of carsharing profits each month. This covers the €2,100 monthly fixed costs of the whole fleet of 7 cars almost 5 times.

Other Implications

A business would have to actively select the people (houses in the surrounding) belonging to the new demand pool and allow them access. When access is granted, an improvement of relationships with real estate owners and residents in the activated surrounding might be a result. The added access to carsharing in front of the door might increase the value of real estates, especially when parking space dedicated for privately owned cars related to the real estate is not available. (This value increase could again translate to financial benefits for the owning business.)

As for the external users, allowing the employees to use the car fleet for private issues (in exchange of a discounted financial compensation) might increase the relationship and improve the resonance employees have towards the business.

Furthermore, a business might be able to leverage environmental benefits resulting from the furthering of carsharing (discussed in following the section) as corporate social responsibility and improve their public reputation.

6.1.2 Benefits for the Environment

Section 2.3 presents environmental benefits from public carsharing found in literature. Since the implementation, proposed in Chapter 5, creates extra public carsharing capacities, similar benefits apply. How these benefits translate under the assumptions from Section 6.1.1 is discussed in the following.

Reduction of Privately owned Cars

According to literature (Section 2.3.1) one full time shared car is able to replace 5-23 privately owned cars. In which way the settings of the situation translate to a replacement potential is not exactly known. In the case of BICS making the business cars part time available to the public when the business demand is low, the replacement potential might fall to the lower end, since a car is not full time publicly shared. However, the periods during which the cars would be available to the public are the most relevant times for carsharing [3].

In the case of the Municipality of Amsterdam, the elaborated public transport system in Amsterdam and the Netherlands in general might be favorable. Furthermore, the home locations of the cars are related in highly populated and densely build areas, which might also be favorable for the replacement potential. However, it could also mean that the average amount of car per new membership household is relatively low, which would reduce the replacement potential.

More research about the residents in the surroundings of the home locations of a business, its employees and the criteria for a high replacement rate is needed to make estimations about how the in Chapter 5 proposed implementations would influence the car ownership of employees and residents in the surroundings of a business. However, literature (Section 2.3.1) indicates that there are relevant potential benefits.

Reduction of Required Parking Area

The reduction of required parking space in an area is directly related to the amount of cars owned in an area and their utilization (i.e., cars which always drive do not park). As just discussed it is difficult to estimate the potential of reducing car ownership in the surrounding of a respective business. Considering the assumptions of Section 6.1.1, the residents in the surrounding of the business occupy one car in average (during the low demand periods). If it is further (conservatively) assumed that this car can replace 5 privately owned cars in the surrounding of the business, this would make 7 parking spaces obsolete in the surrounding of the business (including the 2 parking spaces the business saves). Assuming one parking space is at least 2.40-meter-wide and 4.50-meter-long [31], scrapping 7 parking spaces frees an area of 75.6 square meter. This is more than enough for a small house [14] or a small recreational area.

Reduction of Car Traveling

As for the reduction potential of privately owned cars, the reduction potential for car travel in general does not directly translate from literature (Section 2.3.2). If it can be assumed that there is a relevant potential for reducing the amount of privately owned cars through the concepts introduced in Chapter 5, then there is also a potential to reduce car travel in general.

The earlier described settings of the Municipality Amsterdam case (e.g., elaborated public transport, highly populated and densely build areas) represent a setting which might support the reduction of car travel. However, a risk would be a new membership pool of only non-car owners. Literature shows (Section 2.3.2) that even when the majority of the new membership pool was car-less before getting access to carsharing, the reductions related to the minority of car owners dominated the increase in travel of previously car-less members. However, if the percentage of car-less new members becomes too big, there should be a shifting point where the relatively large car travel reductions from car owners are not able to compensate the mass of small increases.

Reduction of Emissions

Reductions of emissions due to carsharing in literature (Section 2.3.3) mainly result from respective reductions in the total distance traveled by car and that a part of the travels is done with younger and more efficient carsharing cars instead of privately owned cars. As discussed, the exact benefits in these two categories is not clear, although they seem promising. If the assumption holds that privately owned cars can be replaced and total travel distance by car can be reduced, then also the reductions of emissions would be significant according to literature.

6.1.3 Benefits for WeGo

WeGo as facilitator of the carsharing technology, used by businesses, could play a central role in the implementation of the concepts introduced in Chapter 5 and extend its product & service portfolio. This could improve their relationships with existing customers and attract new customers, since the new concepts further the efficient use of BICS, which seems to be a key reason why businesses choose for BICS. Furthermore, as for the businesses, environmental benefits could also translate positively to WeGo's reputation. Besides an increase in customers, the extended portfolio would also generate new revenue streams such as: one-time revenues for advises and implementations, ongoing sale up opportunities, and margins from the profits businesses generate through the commercial bookings. In a small case as the toy problem discussed in Section 6.1.1 a 10 % margin, would mean €1,024 revenues for WeGo each month. When WeGo introduces the new concepts to their system and customers they would have a strong leverage point to demand a margin of the commercial benefits the business owning the respective cars would generate.

6.2 Thresholds

While Section 6.1 shows the potential benefits implied by this research, the integration of a novelty in a system and the associated change always brings challenges and thresholds with it. To understand the feasibility and challenges of the suggested novelties, this section discusses potential thresholds. They are presented in two parts, according to the two major novelties. Section 6.2.1 focuses on thresholds against giving new demand sources access to BICS. Section 6.2.2 focuses on thresholds against the integration of revenue management concepts in BICS.

6.2.1 Against Allowing Private and External Use

The first novelty is the introduction of private use by employees and external users, whereof the latter is the bigger concern. The thresholds from this novelty evolve around the additional demand, partly by (to some degree) unknown users into the system and changing BICS into a direct revenue stream. In the following some threshold topics in respect to these points are discussed.

Trust

As discussed in Section 5.2.1 the owning business has an established relationship of trust and control with its employees. This relationship does not exist with external users. When they are given access to the cars the owning business would have less trust and control with them, than with its employees. Research on pubic carsharing [1] has shown that users treat the shared cars less responsible than they would treat their own cars, which could support companies in hesitating to integrate external users.

Insurance / Lease

The increased user pool, which would include users who are not employees of the owning company, might result in an insurance markup. Research mentions [28] high policies for carsharing and possible difficulties in securing a policy, depending on the type of users. Furthermore, many businesses do not fully own their cars, but lease them. Therefore, the leasing party would also have to be on board, which could make it more difficult to find a leasing party or increase the fees.

Taxation

Understanding how taxation works is always a challenge for lay mans and can be very different per country. In the Netherlands, costs made for company cars can be used to gain tax advantages, however when the cars are also used privately a bookkeeping of all trips made (including their purpose) is required and taxes have to be paid for the private use [20]. Allowing private use by employees and a commercial use by external users, would make the taxation more complicated and probably increase the taxes a business has to pay. It would require an expert to investigate this.

Possible Conflicts with Business Use

Since the main purpose of BICS is to offer mobility for business tasks, a company might be concerned that the new demand sources interfere with the execution of these tasks. This could be directly when capacity needed for business tasks is occupied by an external user or a private booking of an employee. It could also be indirect for example when a car gets damaged during a trip related to one of the new demand sources and therefore does not look representative or is temporarily not available.

Missing Knowledge about new Demand Sources

As indicated in Section 5.3 and 6.1 there are many unknowns when it comes to the private internal demand and even more so the external demand. The employees are known, but their demand for private usage of the cars, perception, and valuation of it are not. The external demand category is completely unknown, since the business has most likely not had any interaction with these users or knows who they are.

Workload

More usage means more issues: faster attrition, more user support requests, more car and user management, more administration. The workload of the car fleet and system management increases when the usage increases. Furthermore, it will happen more often at times which are at this point normally not heavily used by the employees (i.e., evenings and weekend). This means user support has to be extended to be more available at these times. Different types of users do not only mean a quantity increase, but will make the system also more complex, since issues might be different and the administration changes (e.g., as for taxation topics). Furthermore, the launch of such a project would require heavy preparations in different areas (e.g., marketing, sales, operations, and finance).

6.2.2 Against Integrating Revenue Management

The second novelty is the introduction of revenue management-based pricing models instead of constant price settings. The thresholds from this novelty evolve mainly around the complexity of revenue management. In the following some threshold topics in respect to this point are discussed.

Perception of Users

Often mentioned in the context of revenue management pricing is the difficulty for users to understand how prices are determined and a perceived unfairness when prices increase, or different users pay more than others for the same product/service [4]. Users might choose for other carsharing concepts or private cars, when they develop a high resentment towards the revenue management-based system. Furthermore, a resentment towards the pricing of the BICS might translate to the general public image of a business.

Missing Knowledge and Technical Capabilities

As discussed in Section 5.3, revenue management was able to succeed in the airplane industry due to previous experience in other complex operation research field and the use of advanced technical systems [34]. Both capabilities seem to be limited for WeGo (and probably other carsharing players) and most of the involved businesses (WeGo's customers). Therefore, the potential of integrating revenue management into BICS (and carsharing in general) might be limited to simple concepts (like those introduced in Section 5.3) or at least take a lot of time and investment.

Workload

For the integration of revenue management into BICS a lot of preparation and research would be required. Market research to figure out the pricing would be needed. Forecasting models would have to be modeled and tested. WeGo's platform would have to be further developed to support the revenue management models (even when this does not include automated algorithms). The marketing and communication for the pricing would have to be prepared and executed. Furthermore, when the system would be running the prices and forecasts have to be updated frequently to achieve optimal results. Especially when automated systems are missing, this will cost work.

6.3 Solutions

Section 6.2 indicates that there might be some feasibility issues with the novelties proposed by this research. This Section discusses these issues from a different perspective an evaluates in how fare the concerns are applicable and how they could be devitalized. Section 6.2.1 focuses on solving the thresholds related to giving new demand sources access to BICS. Section 6.2.2 focuses on solving the thresholds related to the integration of revenue management concepts in BICS.

6.3.1 Supporting Private and External Use

Section 6.2.1 discusses threshold topics related to the introduction of private use by employees and external users. In this part it is investigated how each of these topics might be solvable.

Trust

Some degree of the anonymity of the external users is taken away by the fact that the owning companies have to give them access. Therefore, a first interchange takes place, which would include the signing of some sort of contract/codex. If as proposed the external users would mainly be residents of the company's surrounding they would also be less distant to the company. Furthermore, by offering access/memberships via real estate owners instead of directly to the end users/inhabitants, a second level of enforcement would be added to indirectly pressure users to be responsible. In addition, the automatic electronic administration, related to the booking system, makes it easy to trace back misconduct (e.g., speeding tickets, damage at the car, or trash laying in the car) and could be punished with fines or taking away a user's access (when mentioned in the usage agreement). A survey among public carsharing users [1] showed, that such control and regulation is to some degree appreciated, since users seem to know that they would behave less responsible if this enforcing presence would be absent.

Insurance / Lease

Literature indicates that while historically it was not always easy to find a policy provider for carsharing concepts this is not the case anymore in recent years [28]. Higher fees might still be the case, but these would probably easily be compensated by the revenues created through the new demand sources (see Section 6.1.1). Lease parties and car dealers are recognizing the carsharing trends in the market and some are actually interested in exploring which opportunities and threads these trends mean for them. Some of such parties already collaborate with WeGo due to this motivation.

Taxation

Companies, which apply BICS are on a scale, which requires them to have dedicated tax advisers. Therefore, the capabilities to handle the taxation specifics for adding a commercial use to the business use of the company cars should already be present. On one hand this might increase a company's taxes (which would be compensated by the generated revenues, as with the insurances), but on the other hand governments might actually be interested in granting companies tax benefits for the possible environmental benefits (Section 6.1.2). This idea is inspired by the fact that the Dutch government already expressed its support of carsharing e.g., through the Green Deal [25].

Possible Conflicts with Business Use

As mentioned in Section 7.2 it would be advisable to only allow business related bookings during times where these occur frequently (the office hours), such that direct interference is not possible. Occasionally business bookings also occur outside of these periods. Especially when forecasting capabilities are (in the beginning still) underdeveloped, capacity made available to the new demand sources should be selected carefully. To prevent these kinds of interference revenue management concepts (i.e., protection levels / booking limits) are proposed as implementation support.

Missing Knowledge about new Demand Sources

While the knowledge is indeed missing, the new demand sources are limited and known. Therefore, they can be surveyed in a targeted manner. Furthermore, adding them to the system in multiple waves, would reduce the pressure and create pilot groups which could be used to gain knowledge. When it comes to finding the right pricing; after an educated start setting (maybe even discounted values as marketing strategy during the startup period) the prices will anyway have to be fine-tuned trough a careful trial and error play with the customers.

Workload

If WeGo helps multiple of their customers to establish such concepts over time, the gained experience would help to reduce the work load of launching these projects more and more. The companies (WeGo's customers) could use the generated revenues to outsource additional administrative and helpdesk work to WeGo. This would mean new revenues for WeGo and they have already experience with these tasks, since some customers already outsource them to WeGo.

6.3.2 Supporting Integrating Revenue Management

Section 6.2.2 discussed threshold topics related to the introduction of revenue management to BICS. In this part it is investigated how each of these topics might be solvable.

Perception of Users

Nowadays revenue management is not new to the public. Especially the travel industry is using revenue management for multiple years to price airplane tickets and hotel rooms. This fact should reduce the novelty issue, when introducing revenue management to carsharing. Furthermore, when attention is payed to a clear communication and explanation of how prices are determined, customers perception can be improved [4].

Missing Knowledge and Technical Capabilities

The airline industry has driven revenue management theories to a sophisticated state. Knowledge established in this and other industries can be borrowed and as mentioned in Section 5.3 these industries also had to start somewhere. Revenue management models can be made very simple (e.g., different standard prices during the week and the weekend) and already achieve some results, without requiring extensive knowledge and technical capabilities. Due to WeGo's facilitating role in the BICS market, they would have an interesting position to acquire the necessary capabilities to add revenue management systems to their portfolio and poll the efforts. If they want to make this active step investments inhuman capital and the system development would be necessary.

Workload

The most efficient way for reducing the workload regarding the introduction and maintenance of revenue management concepts, again seems to be a central party (e.g., WeGo), which could pool the efforts form multiple BICS concepts and capitalize the experience.

6.4 Chapter Conclusion

This chapter presents the last new content of this research. Section 6.1) elaborates benefits for creating an incentive for the earlier established concepts. Furthermore, Section 6.2 discusses thresholds, a possible implementation would present, and Section 6.3 suggests possible solutions for these thresholds. The following reflect on this discussion and previous parts to make recommendations for some choices.

Chapter 7

Choices

Chapter 5 discusses different options for the improvement of BICS in context of this research. Chapter 6 points out benefits and thresholds, related to these options. This chapter reflects on these insights and makes recommendations about which choices seem most promising to improve BICS (Section 7.1). Furthermore, it presents a road map for a possible integration of these recommendations (Section 7.2).

7.1 Where to Focus on

Chapter 5 presents multiple options, which all have their own relevance for the improvement of BICS in respect to the reduction of demand disparity with the goal of financial and environmental benefits. This section evaluates these options based on a cost vs. benefit mindset and recommends on which options to focus the effort due to the related promising results.

7.1.1 Neglect the Reduction of Peak Demand

Chapter 5 discusses two directions of decreasing the demand disparity in BICS. The first recommendation is to not focus on reducing the peak demand (which could lead to a reduction of BICS fleets). This recommendation is not motivated by the fact that a reduction of the amount of cars in a BICS system might be a conflict with WeGo's business model. It is motivated by the low success expectations compared to the necessary efforts and the higher potential for benefits a bigger fleet holds.

Although reducing the peak usage of BICS would improve BICS, since it would enable a reduction of the fleets and thus less costs and environmental strains, the actual results are indicated to be limited. This indication is based on the origin of BICS peak demand (Section 1.3.2 and 4.2) and experiences in the literature with the general reduction of car travel (Section 2.1). Furthermore, the related efforts are relatively high compared to the expected gains (Section 5.1.1). Additionally, reducing the usage and therefore fleet size, reduces the resources for the potential of some benefits mentioned in Section 6.1.

7.1.2 Focus on Increasing Demand in Low Demand Periods through New Demand Sources

When the demand disparity of BICS is not reduced by reducing the peak demand, the demand has to be increased in the periods where it is low. Although this direction also is related to some efforts, the gains seem more promising and efforts should directly increase the gains.

There are two potential sources for the desired demand: the internal private use of employees and the external users. While one source, the internal private use, is promising since the users already have access to the system and are trusted by the company (Section 5.2.1), the other source is promising due to the controllability of its size and the expected timing of its demand (Section 5.2.2). Next to the more promising reduction of the demand disparity and related increased efficiency of BICS, this recommendation is motivated by the potential financial and environmental benefits of this approach

(Section 6.1). The efforts are mainly related to the implementation and maintenance of the new demand sources and optimization of a potential revenue management model for the integration, which is discussed more in the following section. The results are more directly related to the respective efforts, than the efforts for reducing the peak demand (car travel in general).

7.1.3 Implement Revenue Management to Optimize Outcomes

Without the support of revenue management concepts (or any other supportive measures) the integration of the two new demand sources becomes hardly feasible. The capacity control rules (Section 5.3.2) are necessary to ensure that the capacity is allocated according to a company's prioritization. If they are missing, the risk is that a company's business operations are compromised. Furthermore, the right pricing strategy (Section 5.3.3) will optimize the utilization (thus reduce the demand disparity of BICS to a minimum) while maximizing profits. An optimized utilization also maximizes the environmental benefits (Section 6.1) the available resources have.

Develop Forecasting Capabilities

The reliability of demand forecasts has direct influence on the appropriateness of capacity control rules and the understanding of the impact of different pricing strategies. If forecasts are not reliable, protection levels for high priority categories (i.e., business demand) tend to be set too carefully, which can lead to unutilized capacity. Furthermore, not having an understanding of the results of changes in the pricing strategy, makes it hard to find a strategy which optimizes the utilization and related profits. Therefore, it is recommended to invest in establishing forecasting capabilities.

Let the New Demand Categories Compete

While the internal private demand gets the preference when it comes to trust and control from the company, the external demand shows more potential when it comes to financial and environmental benefits (Section 6.1). Furthermore, additional layers of booking limits increase the risk of underutilization. In this regard it is recommended to let these two demand categories compete for the same capacity (i.e., only protect capacity for the business demand). The private internal category of the employees could still be given an advantage by letting them request bookings earlier in advance and giving them more discounted price quotations. Moreover, since the different categories might behave differently to certain pricing strategies and a company might have different objectives for each category, it is recommendable to handle separate pricing strategies (i.e., pricing tables) for each category.

7.2 Integration Road Map

As discussed in Section 5.3.1, it took the airline industry decades to reach the current advancement level of revenue management. Although the concepts introduced in Section 5.3.2 and 5.3.3 are hold simplistic in consideration of the inexperience of BICS, an integration would have to happen in phases. At the moment the only familiar demand category is the business-related bookings. Therefore, the following recommendations for an implementation are presented, based on the recommendations from the previous Section. For every step of the integration a time table planning is indicated. It should be mentioned, that this time table is indicated for a first integration. It should be expected, that it shortens for following integrations, due to the gained experience and capabilities from previous projects.

Understand the Situation: Develop and test a forecasting method on the currently familiar demand category (business related bookings), till the capability to make robust forecasts is acquired. *(1 month)*

Understand a possible 1st Expansion: Research how employees stand towards using the shared cars for private purposes (timing and volume of demand, price sensitivity). *(1 month)*

Prepare and Execute the 1st Expansion: Set protection levels for the business-related demand, come up with a simple pricing table (e.g., only considering the time slots involved in a booking, not how far in advance the request was placed or the free capacity at the moment of booking) for the private internal demand category and give it access to time slots outside the regular office hours. *(2 months)*

Optimize the 1st Expansion: • Introduce more complex pricing tables (e.g., add the two dimensions left out earlier) and optimize the utilization and profit while observing how the private internal demand responds to changes. (The acceptance of complex pricing due to revenue management models increases when the logic behind them is clearly communicated with the user [4]). *(6 months)* • Acquire the capability to forecast the private internal demand related to the optimal pricing strategy. *(2 months)*

If the cars are still underutilized:

Understand a possible 2nd Expansion: Research how residents in the surrounding of the business stand towards using the shared cars outside a companies office hours (timing and volume of demand, price sensitivity). *(1 month)*

Prepare and Execute the 2nd Expansion: Set protection levels for the private internal demand (only if this category is prioritized above the external demand, which is not recommended in Section 7.1), come up with a pricing table for the external demand category and give a pilot group of external users access to time slots outside the regular office hours. This pricing table could be as advanced as the pricing table for the private internal demand (if communicated correctly) and based on the previously gained experiences. *(1-2 months)*

Optimize the 2nd Expansion: • Optimize the utilization and profit while observing how the external demand responds to changes in the pricing strategy. *(6 month)* • Acquire the capability to forecast the external demand related to the optimal pricing strategy. *(1 month)* • If necessary increase the group of external users and repeat the optimization loop.

For simplicity this approach stays away from the already high utilized office hours. Furthermore, the acceptance for allowing bookings besides for business related usage during office hours might be low. When forecasting capabilities reach a confidently robust level and there are certain days with lower utilization during office hours (e.g., Fridays) this mindset could in theory be changed. Even if it is recommended (Section 7.1) to let the private internal demand and external demand compete for the same capacity (no protection level for the private internal category), it makes sense to integrate them not at the same time. By integrating them in two expansion waves the uncertainty is reduced. The first expansion can be seen as a pilot with the employees, who are already accustomed to the system and have a relationship to the company. Building up forecasting and revenue management experiences with them reduces the uncertainty for a possible second expansion of the external category.

7.3 Chapter Conclusion

This chapter reflects on previous chapters and evaluates insights gained. It makes recommendations which choices to make and how they could be implemented to achieve the best outcome. The next/last chapter summarizes and concludes this research and points out future research implied by it.

Chapter 8

Conclusion & Discussion

This final chapter recaps the executed research, its primal motivation, the guiding central research question, the methods used to answer the central research question, the achieved results and recommendations going forward.

8.1 Motivation

The motivation of this research is in line with the fundamental idea of carsharing. Privately owned cars are not utilized a majority of time, during which they require parking space. The fundamental idea of carsharing is that sharing increases the utilization of cars, which leads to less cars and therefore parking space being needed. This research assumes that WeGo's BICS successfully furthers the carsharing idea, but as currently executed stays below its potential. The motivation of this research is to help WeGo to better realize the potential of BICS, by driving the carsharing idea further to achieve financial benefits for WeGo's customers and sustainability benefits for their environment.

8.2 Central Research Question

This research assumes that the reason why BICS stays below its potential is a disparity of its demand through the week. Therefore, driven by its motivation the following research question is used as guidance for this research:

How can a two-way demand regulation (reduction of peak demand and demand promotion in periods of low utilization) make the use of a business internal car sharing fleet more efficient and sustainable?

8.3 Methods

To answer this central research question, in a hypotheses driven approach, different methods are executed. Multiple literature topics are reviewed, to establish insights for other parts of the research. The Municipality of Amsterdam (a WeGo customer) is used as case to get an understanding of the current execution of BICS. The case specifics are discussed, and its booking data is analyzed to get a good indication for the demand disparity of BICS, its extent and causes. The literature insights are used to come up with options to improve BICS. Revenue management concepts are introduced as means of supporting these options. To understand the feasibility of improving BICS with the mentioned options, their benefits and thresholds are discussed. Based on the necessary efforts and expected benefits, recommendations are made which options to choose to achieve an improvement of BICS.

8.4 Results

Executing this methodology, the following results are achieved.

8.4.1 Achievements

This research is based on the hypotheses, that the potential of BICS is not realized due to its current use, which causes underutilization over long periods, and could only be changed when peak demand is reduced, or extra demand is created in periods of low utilization. Throughout the research these hypotheses are confirmed. While the possibilities to lower peak demand of BICS seems limited due to its purpose, increasing the demand in periods of low utilization, through new demand sources, seems promising and brings potential benefits in multiple areas with it. These benefits are not only more efficient and profitable BICS for the owning companies, but also show huge potential for the environment of and around those businesses. Furthermore, for the facilitator of these BICS concepts and company behind this research, WeGo, opportunists and new revenue streams are found. To protect the current use of BICS and optimize the utilization and profit from the new demand sources revenue management is introduced. It is found that revenue management has huge potential in the carsharing industry and simple models for a first implementation are presented. However, there seem to be some feasibility issues with the introduction of new demand sources to BICS and the implementation of revenue management. For almost all related thresholds there are solutions, but they still form a concern.

8.4.2 Discussion

The appropriateness of the data analysis of the provided booking data is already discussed in connection with the analysis. While it gives the necessary insights for this research, for an actual implementation of the proposed concepts a more accurate analysis might be necessary to establish trustworthy forecasts.

It is assumed that the new demand sources hold a strong potential to increase the utilization of BICS during its periods of low utilization. This assumption is supported by only little literature findings and not by any market research. Therefore, the extend of new demand and how it would respond to carsharing and revenue management-based pricing is still unsure. If a research would show that almost no new external users own a private car, then the environmental benefits could strongly be compromised.

Originally, interviews with the Municipality of Amsterdam and a second customer of WeGo, which recently implemented a concept which allows employees and specific external people to use its cars for private bookings, were desired to be conducted. Unfortunately, these parties were not available for interviews, which limits this research when it comes to the understanding how carsharing is use within the Municipality of Amsterdam, what they think about new demand sources and revenue management.

8.5 Recommendations

Surveying WeGo's customers to get an understanding of their perception towards letting their employees and externals use their cars for private bookings, and revenue management-based pricing would be interesting to see what the market potential of these concepts is. Additionally, a market research especially of the external user group, would be interesting to see what their demand is, how they would react to carsharing access and different price settings.

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Appendix A

Tables

Table A.1: Distribution of Cars over the 6 Organizations of the Municipality Amsterdam

Organisation	DBGA	FBA	GGD	GP	SC	SZO	Total
Amount of Cars	1	52	2	1	5	1	62

Table A.2: Distribution of Bookings over the 6 Organizations of the Municipality Amsterdam

Organisation	DBGA	FBA	GGD	GP	SC	SZO	Total
Amount of Bookings	130	14,967	10	1	486	1	15,595

Table A.3: Distribution of Cars within the FBA organization

Home Location	Amount of Cars
Bijlmerdreef	2
Buikslotermeerplein	2
Gelrestraat	3
Herikerbergweg	1
Jan van Galenstraat	10
King's Cross	1
Leeuwendalersweg	2
Weesperbuurt	21
Osdorpplein	1
Polderweg	1
Rozenburglaan	5
Waterlooplein	1
Wilhelmina Bladergroenstraat	1
Willem Theunisse Blokstraat	1
Total	52

Table A.4: Distribution of Cars within the FBA organization

Home Location	Amount of Bookings
Bijlmerdreef	449
Buikslotermeerplein	240
Gelrestraat	296
Herikerbergweg	862
Jan van Galenstraat	2168
King's Cross	490
Leeuwendalersweg	348
Weesperbuurt	8915
Osdorpplein	22
Polderweg	190
Rozenburglaan	298
Waterlooplein	203
Wilhelmina Bladergroenstraat	159
Willem Theunisse Blokstraat	327
Total	14967

Table A.5: Distribution of Booking Statuses of the Weesperbuurt Cluster

Booking Status	Amount
Afgebroken	1842
Afgerond	7071
Geaccepteerd	2
Grand Total	8915

Table A.6: Distribution of Booking Statuses of the Weesperbuurt Cluster Jan.-Aug.2017

Status	Total
Completed	1,564
Canceled before Start	301
Canceled after Start	105
Grand Total	1,970

Table A.7: First Insights about Average and Maximum Utilization per Time Slot in a Week

	Utilization per weekday													
	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
Time Slots	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
00:00	1.83	5	1.79	5	2.31	7	2.22	7	2.33	7	2.16	6	2.16	6
00:30	1.83	5	1.79	5	2.31	7	2.22	7	2.34	7	2.16	6	2.16	6
01:00	1.83	5	1.78	5	2.31	7	2.22	7	2.33	7	2.15	6	2.16	6
01:30	1.83	5	1.78	5	2.31	7	2.22	7	2.33	7	2.15	6	2.16	6
02:00	1.83	5	1.78	5	2.31	7	2.22	7	2.33	7	2.15	6	2.16	6
02:30	1.82	5	**1.78**	5	2.31	7	2.21	6	2.33	7	2.15	6	2.16	6
03:00	1.82	5	1.78	5	2.31	7	2.21	6	2.33	7	2.15	6	2.16	6
03:30	1.83	5	1.78	5	2.31	7	2.20	6	2.33	7	2.15	6	2.15	6
04:00	1.83	5	1.78	5	2.31	7	2.20	6	2.33	7	2.14	6	2.14	6
04:30	1.83	5	1.79	5	2.32	7	2.20	6	2.33	7	2.13	6	2.12	6
05:00	1.83	5	1.80	5	2.32	7	2.21	6	2.33	7	2.06	6	2.10	6
05:30	1.87	5	1.80	5	2.32	6	2.22	6	2.33	7	2.06	6	2.10	6
06:00	1.95	5	1.82	5	2.35	6	2.24	6	2.40	7	2.06	6	2.10	6
06:30	2.31	6	2.13	6	2.82	6	2.69	7	2.81	8	2.06	6	2.10	6
07:00	3.04	7	3.07	8	3.71	8	3.50	10	3.31	8	2.06	6	2.09	6
07:30	4.06	10	4.10	10	4.62	9	4.61	12	3.94	10	2.08	6	2.09	6
08:00	4.81	10	4.72	10	5.87	11	5.71	12	4.82	10	2.08	6	2.08	6
08:30	5.45	10	5.62	11	6.71	11	6.55	12	5.42	11	2.08	6	2.09	6
09:00	5.82	11	5.90	11	7.06	11	6.80	12	5.56	11	2.07	6	2.09	6
09:30	6.23	12	6.34	12	7.41	12	7.71	13	5.74	11	2.07	6	2.09	6
10:00	6.42	12	6.54	12	7.52	12	7.87	14	5.91	11	2.07	6	2.08	6
10:30	6.70	12	6.83	11	7.75	13	8.15	14	6.04	11	2.08	6	2.08	6
11:00	6.71	13	6.91	12	7.70	13	8.22	14	6.15	11	2.08	6	2.08	6
11:30	6.92	13	7.32	12	8.07	14	**8.64**	14	**6.23**	11	2.08	6	2.08	6
12:00	6.99	13	7.34	12	**8.25**	14	8.55	15	6.13	12	2.08	6	2.08	6
12:30	**7.00**	12	**7.36**	12	8.19	14	8.40	14	5.96	12	2.08	6	2.08	6
13:00	6.84	12	6.90	12	7.73	14	8.02	14	5.74	11	2.07	6	2.08	6
13:30	6.69	11	6.90	12	7.55	13	8.06	13	5.71	11	2.08	6	2.08	6
14:00	6.38	11	6.64	12	7.31	13	7.69	13	5.31	11	2.05	6	2.07	6
14:30	6.29	10	6.48	11	7.31	13	7.48	13	5.06	11	2.05	6	2.06	6
15:00	5.87	11	6.03	11	6.89	14	6.94	13	4.65	10	2.04	6	2.06	6
15:30	5.31	11	5.79	11	6.35	13	6.59	12	4.45	10	2.09	6	2.06	6
16:00	4.63	10	5.00	10	5.61	12	5.95	12	3.89	9	2.09	6	2.05	6
16:30	4.18	9	4.71	10	5.03	10	5.46	12	3.40	8	2.15	6	2.05	6
17:00	3.33	8	3.60	8	4.22	9	4.59	12	2.81	7	2.13	6	1.98	6
17:30	3.01	8	3.24	8	3.81	9	4.18	11	2.68	7	2.15	6	1.97	6
18:00	2.62	8	2.85	7	3.27	7	3.42	10	2.40	7	2.13	6	1.96	6
18:30	2.17	7	2.69	7	2.63	6	2.92	9	2.29	6	2.15	6	1.92	6
19:00	1.96	7	2.52	7	2.48	6	2.66	9	2.28	6	2.16	6	1.90	6
19:30	1.92	7	2.42	7	2.43	6	2.57	8	2.22	6	2.16	6	1.89	5
20:00	1.88	7	2.38	7	2.32	6	2.43	8	2.21	6	2.17	6	1.89	5
20:30	1.85	6	2.38	7	2.31	6	2.41	7	2.20	6	2.17	6	1.88	5
21:00	1.83	6	2.36	7	2.27	7	2.39	7	2.18	6	2.17	6	1.88	5
21:30	1.81	6	2.34	7	2.27	7	2.39	7	2.17	6	2.17	6	1.87	5
22:00	1.80	5	2.33	7	2.26	7	2.38	7	2.17	6	2.17	6	1.83	5
22:30	1.80	5	2.32	7	2.24	7	2.38	7	2.17	6	2.17	6	1.83	5
23:00	1.80	5	2.32	7	2.23	7	2.38	7	2.17	6	2.17	6	1.83	5
23:30	1.79	5	2.31	7	2.22	7	2.33	7	2.16	6	2.17	6	1.83	5

Table A.8: Utilization State per Time Slot throughout the Week

	Utilization State per weekday						
Time Slots	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
00:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
00:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
01:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
01:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
02:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
02:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
03:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
03:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
04:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
04:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
05:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
05:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
06:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
06:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
07:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
07:30	LOW	TRANS.	TRANS.	TRANS.	LOW	LOW	LOW
08:00	TRANS.	TRANS.	TRANS.	TRANS.	TRANS.	LOW	LOW
08:30	TRANS.	TRANS.	PEAK	PEAK	TRANS.	LOW	LOW
09:00	TRANS.	TRANS.	PEAK	PEAK	TRANS.	LOW	LOW
09:30	TRANS.	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
10:00	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
10:30	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
11:00	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
11:30	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
12:00	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
12:30	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
13:00	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
13:30	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
14:00	PEAK	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
14:30	TRANS.	PEAK	PEAK	PEAK	TRANS.	LOW	LOW
15:00	TRANS.	TRANS.	PEAK	PEAK	TRANS.	LOW	LOW
15:30	TRANS.	TRANS.	PEAK	PEAK	TRANS.	LOW	LOW
16:00	TRANS.	TRANS.	TRANS.	TRANS.	LOW	LOW	LOW
16:30	TRANS.	TRANS.	TRANS.	TRANS.	LOW	LOW	LOW
17:00	LOW	LOW	TRANS.	TRANS.	LOW	LOW	LOW
17:30	LOW	LOW	LOW	TRANS.	LOW	LOW	LOW
18:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
18:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
19:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
19:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
20:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
20:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
21:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
21:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
22:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
22:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW
23:00	LOW	LOW	LOW	LOW	LOW	LOW	LOW
23:30	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Table A.9: Bin sizes, respective frequencies and cumulative percentages indicating how long before their booking period bookings are created. Figure 5.2 is retrieved from this data. This is based on the booking data of the relevant cluster form the Municipality of Amsterdam from January till August 2017

Time Bin (in days)	Frequency	Cumulative %
0	29	1.48%
0 - 0.5	676	36.02%
0.5 - 1	246	48.59%
1 - 2	152	56.36%
2 - 3	85	60.71%
3 - 4	75	64.54%
4 - 5	76	68.42%
5 - 6	64	71.69%
6 - 7	65	75.01%
7 - 8	47	77.41%
8 - 9	28	78.85%
9 - 10	19	79.82%
10 - 11	14	80.53%
11 - 12	18	81.45%
12 - 13	17	82.32%
13 - 14	15	83.09%
14 - 15	12	83.70%
15 - 16	15	84.47%
16 - 17	9	84.93%
17 - 18	10	85.44%
18 - 19	8	85.85%
19 - 20	9	86.31%
20 - 21	6	86.61%
21 - 22	9	87.07%
22 - 23	7	87.43%
23 - 24	7	87.79%
24 - 25	11	88.35%
25 - 26	7	88.71%
26 - 27	7	89.06%
27 - 28	7	89.42%
28 - 29	5	89.68%
29 - 30	1	89.73%
30 - 60	162	98.01%
More than 60	39	100.00%

Appendix B

Supplements

B.1 Business Internal Carsharing and Measures for Reducing Car Use

Section 2.1 lists travel demand management measures researched by Stradling et al. [32]. How these measures might apply to BICS is indicated in Section 5.1.1. In the following this topic is continued. It is discussed which measures might be relevant for the context of this research. The relevant measures can be influenced by the respective business (not considering the legislative powers in case of the Municipality of Amsterdam).

M1 Teleworking

Nowadays the telecommunication technology is advanced enough to enable effective meetings without requiring all participating parties to be in the same place. In developed countries such as the Netherlands, the networks are stable and data transmission is fast enough to enable telecommunication with neglectable delay. Commonly used video conference tools, such as Skype, and the quality of modern web cams enable the participating parties to see each other in high quality. Furthermore, these programs can be used to share documents and slides during a remote meeting.

Most businesses already have the necessary technology in their facilities. Moreover, these technologies are seen as standard in every modern laptop. However, as far as the technology has advanced it still does not equal the experience of meeting each other in person (and maybe never will). Therefore, without a mayor culture change in the involved societies, telecommunication will never fully replace the need to travel for meetings. However, a realistic culture and policy change within businesses should be able to promote telecommunication in order to reduce travel demand related to meetings.

M2 Improved infrastructure for walking and biking

Businesses normally do not have a direct influence on the facilities outside of their properties. However, they can influence the location and facilities of their properties. When the facilities of a business are located closer to the places where its employees travel, their employees might be more likely to choose walking, biking, or pubic transport (as shown in Table 2.2, Stradling et al. found, that shorter overall journey and interchange times on public transport have potential to reduce car use) instead of driving to satisfy travel demand. Although, relocating facilities of a business is in many cases not be realistic, reallocating employees between existing facilities might be more realistic. Furthermore, businesses can design their facilities to promote other means of travel. Installing changing rooms with showers would be a way to support biking as means of travel.

Besides the choice of location and design of facilities, the excess to other travel options can be influenced a business. Offering free access to a fleet of bicycles, next to a car fleet, would increase the excess to different travel options.

M3 Information campaigns about negative effects of car use
Although the push measure of information campaigns about negative effects of car use are not very effective according to Stradling et al. (see Table 2.2, they could be a low-cost addition to a multidimensional approach of a business to reduce car travel demand. Wright and Egan [37] formulated marketing strategies to reduce car use in a pull manner (by promoting the benefits of alternative travel options), which should make this measure more effective. More to this topic, will follow later in this section.

M4 Social modeling where prominent figures use alternative travel modes
Every change project within a business requires leadership dedication to be successful. In the context of a business, prominent figures are represented through management and senior level stuff. If they do not act as role models / change agents, by reducing their travel demand or choosing alternative travel modes than cars, it becomes more difficult to confine the rest of the business: 'If they do not, why should I'. Although a change can be successfully executed through a bottom up approach, leadership commitment will make success more likely.

M5 Much cheaper [alternative] transport
The aforementioned offering of a free accessible fleet of bikes would provide employees with a cheap travel alternative to cars (for short to medium travel distances). Furthermore, many companies (in the Netherlands) offer their employees travel budgets which can e.g., be used to acquire a business travel card for public transport, basically enabling employees to travel for free with most public transport providers. Promoting these as replacements for car travel could reduce the demand for car traveling.

M6 A ticketing policy so that 1 ticket covers different forms of transport
When a BICS is already in place, the employees would only have to worry about biking and public transport. A solution to cover biking has been discussed above. In the Netherlands all public transport providers can be accessed with one public transport chip card. However, this is not the case in most other countries. In countries like Germany, which are technologically less developed, the corporation between different public transport providers is not as common and local providers lack the necessary technologies. Paper tickets are still the norm for many local providers, while the biggest national railway provider (Deutsche Bahn [DB]) offers the use of digital tickets (e.g., QR-codes on mobile phones) and chip cards for users with subscriptions. In these countries businesses are not yet able to offer their employees the mentioned support. As mentioned, businesses in the Netherlands are more fortunate. The main railway provider in the Netherlands (Nederlandse Spoorwegen [NS]) offers rental bikes at train stations, which can be accessed with the mentioned chip cards. Furthermore, the NS recently enabled the use of certain carsharing providers (Greenwheels) for customers with special business travel chip cards [21].

M7 More readily available information about transport
Nowadays there are websites and mobile applications which can be used to plan travels and get live updates about delays for all public transport providers. Businesses can support their employees by generating fitted travel advice reports based on their travel behavior. More to this topic, will follow later in this section.

M8 Vouchers from employers to subsidize the cost of season tickets
By offering employees the opportunity to get the aforementioned business travel cards (in the case of the Netherlands), businesses would be able to reduce the use of the BICS fleet by promoting other travel options.

B.2 Possible Approach for Travel Awareness Campaign by WeGo

Section 2.1 introduces the concept of travel awareness campaigns, which aim to reduce car travel. Section 5.1.1 mentions how such a campaign could be interesting for BICS and which role WeGo could play in the facilitation of such a campaign. In the following a four phased travel awareness campaign, based on Rose et al. [27], for a possible implementation in a BICS concept within WeGo's system is sketched.

P1 The first phase starts with establishing why and how a reduction of car use should and can be achieved. Rose et al. suggest using a prominent local figure [27] in the awareness creation process. This has also been discussed in the aforementioned measures (see measure M4). While the why part has a more push nature (see measure M3), which can include cost and environmental aspects, the how part should include a pull motivation when explaining ways of car use reduction. Since pull measures seem to be more effective than push measures [32], the focus should be on creating a pull orientated campaign. The discussing of why car use should be reduced should therefore not focus on the negative environmental impacts of cars, but on the lesser environmental strain caused by alternative travel options. The how part can be used to create awareness for some of the aforementioned measures (e.g., M1, Teleworking).

After informing the participants a first round of data collection of their car travel behavior is conducted. For this purpose, Rose et al. distributed diaries, in which the participants could register their trips (including information like distance, purpose, used vehicle). To increase the participation rate of the studied households, included ways of creating peer pressure by making the diaries visible for all members in a household [27]. In case of a BICS, which makes use of WeGo's system, most of the important information for the diaries are already automatically registered in the system. Not automatically registered information (e.g., the purpose of a trip) can be registered via the mobile application, which can also be used to book cars. The higher ease of filling in less information digitally, might increase the participation rate.

P2 During the second phase the collected data from the first phase is analyzed and personalized reports per participant are created and distributed. These reports include information about the frequency, total distance, and environmental impact of the trips a participant made during the first phase. Furthermore, the reports include advice and tips on how the participant could reduce the use of cars. Advises might consider relevant public transport connections to frequent travel destinations (related to M7), trip chaining proposals [27] and the respective achievable improvements.

It might be an interesting idea, which should not require a high workload, for WeGo to implement models in their system, which automatically calculate the environmental impact of a trip or reservation.

P3 The third phase starts with a goal setting, for the reduction a participant aims to achieve. The created handouts should be used to set realistic goals, but to achieve a better outcome the goals should also be ambitious [7]. To create extra motivation through group charisma a business could also choose to set goals for whole teams/departments, where team members motivate each other to reduce the personal usage to achieve the common goal. Furthermore, creating a competitive game between or within teams/departments could also contribute higher reductions.

After the goals are set a second round of data collection takes place, during which the participants are encouraged to implement the suggested changes for their car travel behavior.

P4 The last phase begins with generating a final report, based on the second data collection round and a comparison of the before and after car use. This can be used to evaluate the goal settings. In case of a gamification rewards can be given to the best achievers. The final report furthermore includes advise on how to sustain the achieved reductions (e.g., by making them habits [7] or even improve them.