Improving travel need facilitation using registered travel data

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UNIVERSITY OF TWENTE.

Capgemini
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IMPROVING TRAVEL NEED FACILITATION USING REGISTERED TRAVEL DATA

Thesis

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PREFACE

This report is the result of my master thesis research at Capgemini in Utrecht. By successfully finishing this research, I have obtained my Master’s degree in Business Administration. Researching the topic of employee business transport for half a year has been very educational. During my time at Capgemini, I also got a good impression what working at an IT consultancy firm encompasses.

I would like to express my sincere gratitude towards my commission for their help. Thank you Yvonne Kolen, for your time, patience, enthusiasm, knowledge, and sympathy. Thank you Henk Kroon, for your constructive feedback, flexibility, and enthusiasm. Thank you Peter Schuur for your feedback during the last stages of my research. And finally thank you Rutger Katz, for helping me successfully start my graduation assignment, and for providing me with good suggestions during the early stages of my graduation assignment.

I would also like to thank my colleagues at Capgemini, who helped me with a lot of ad hoc questions, and who made me feel part of Capgemini.

I already thanked my sister and my parents during my last graduation. Therefore I would like to thank Pieter, our family house cat this time. Pieter, thank you for skinning me alive for the last 3 years at my parents’ house, you have been one of my motivations to move out and get a place of my own.

Lastly I would like to thank Gerdine for her love and support during my graduation assignment. You make me a better man.

Jasper Hoeve

Utrecht, April 2016

SUMMARY

In order to facilitate the travel needs of its employees (both commuting and non-commuting), it is not uncommon for firms to provide a company car as part of a fringe benefit compensation package (De Borger & Wuyts, 2011). However, a large company car fleet can be undesirable for business owners from a cost and environment perspective. For example, the Dutch Capgemini branch spends 40 million (or 5% of its yearly revenue) on 3000 company cars (Knol, 2015). Due to environmental awareness, maintaining a large company car fleet also negatively influences the public image of a company (Vogt, 2014). Instead of offering employees a lease car as the baseline, the employer could facilitate employee mobility instead. When offering mobility, travel needs are assessed and the optimal method of transportation is then chosen. This new approach could reduce the lease car usage of the Capgemini employees, and result in financial and environmental benefits for Capgemini.

Companies with a large car fleet usually register the business related travels of their employees for billing purposes. This data can also be used to discover the opportunities and expected benefit of changing the company policy (offering mobility instead of cars). This study analyses the travel patterns of company car users which are then used to discover and value the 'big wins'[1] of changing the way travel needs are satisfied.

The travel patterns of the lease car using Capgemini employees are analysed. This information is then used to suggest alternative ways to satisfy their travel needs. The travel pattern analyses revealed that business trips are overwhelmingly performed within the Netherlands. Although a large number of unique locations are visited, a relative small amount of origin/destination combinations are frequently visited. A conglomeration of cars occurs during business hours, decentralization of cars occurs outside of business hours. The Capgemini lease cars are primarily used for commuting. However, a significant number of non-commuting trips are also performed using the lease cars.

The filtered dataset is used in combination with the knowledge gathered by analysing the employee travel patterns to find and value trips that could have been performed more efficiently. A number of trip alterations are considered: Carpooling, using the train instead of the car, travelling by bicycle instead of by car, encouraging employees to work at the nearest Capgemini office and using the shared car pool more. Studying these opportunities in isolation revealed that using the train or the bicycle during the whole day will result in the largest trip reductions for Capgemini. Up to 8.65% of the lease car trips could have been performed using the train and up to 4.97% of the lease car trips could have been performed using a bicycle. Carpooling is only interesting when combined with other alternative travel opportunities. The potential of using shared cars more often is small. It is also questioned whether employees often have a choice at which Capgemini location they can work, therefore no hard conclusions are made about this travel opportunity. More research is required. Combining the different travel need satisfaction opportunities can result in a reduction of up to 17.2% of all lease car trips. This trip reduction is mostly achieved by taking the bicycle and train more often. The big winners for alternative transport opportunities are therefore the bicycle and the train.

When employee travel needs are satisfied differently in order to achieve financial benefits, 48,336 euro cost reduction per year can be achieved (cost reduction of 0.12%). This cost reduction is primarily achieved by using the bicycle more often. Using the train more often actually results in an increase instead of a decrease in travel expenses. Therefore, train usage should not be encouraged when cost reductions are desired. When environmental benefits are pursued, the CO_2 emission can be reduced by 660,075 kg per year (CO_2 emission reduction of 7.93%). The environmental benefits are primarily achieved by using the bicycle and train more often. The reduction of CO_2 comes with a price tag of € 378,298 per year due to the increase in train travel costs

This study did not reveal any significant benefits for Capgemini by switching from offering lease cars to offering mobility. The majority of business trips (82.8%) still need to be performed using a lease car, regardless of the mobility policy. However, this study did reveal the beneficial effects of promoting train and bicycle usage when possible. Capgemini will be better off to continue to offer lease cars to its employees as the baseline, and promote usage of bicycle and train for its environmental and health benefits.

[1] The 'big wins' are defined here as the improvement of employee travels that covers simple mobility policy changes (promoting car sharing, using public transport, taking the bicycle) that are expected to result in substantial financial and environmental benefits.

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1. INTRODUCTION

1.1 BACKGROUND

In Europe and the USA most people need to travel from their home to their job a number of times per week. The mean distance people need to travel to their job is increasing in Europe and the USA (Nilles, 1991; Van Acker & Witlox, 2011; Jarosz & Cortes, 2014). The 2008 economic recession made jobs more scarce, which contributed to the longer commuting distances for a number of people (Rose, 2013). To maximize opportunities for commuting and to minimize the chance of forced reallocation due to employment dislocation, residences are increasingly chosen for their access to multiple labour markets (Hardill & Green, 2003). These developments have resulted in an increased travel demand by employees.

FIGURE 1 INTENSITY OF TRAFFIC ON ROADS IS INCREASING DUE TO INCREASED TRAVEL DEMAND

The work related travel need is created by employees and employers. Commuting is an important business activity for employers because it enables its employees to perform the work where it is needed. Non-commuting work related travel is an equally important business activity. Businesses depend on communication and interaction between persons working at different locations. In this digital age, face to face communication still outperforms virtual working methods (Andres, 2002; Kiesler & Cummings, 2002). Due to geographically expanding markets, non-commuting business travel has increased considerably over the past few decades (Gustafson, 2012). A certain level of travel flexibility is expected of workers, but especially of managers and professionals (Hardill & Green, 2003). In order to fulfil these travel demands, multiple modes of transport (e.g., by foot, bicycle, train, bus or car) are available. These modes of transport are all used for both commuting and non-commuting business travels.

1.2 RESEARCH MOTIVATION

In order to facilitate the travel needs of its employees (both commuting and non-commuting), it is not uncommon for firms to provide a company car as part of a fringe benefit compensation package (De Borger & Wuyts, 2011). "A company car is a vehicle paid for by the employer but used by the employee for both work and non-work related trips" (Cohen-Blankshtain, 2008, p. 66). Due to the large workforce that needs to travels for business, a large number of cars on the road (or parked at work/home) are actually company cars. In fact, in most European countries 50% of all new registered cars are intended to be used as company cars (Copenhagen Economics, 2009). In 2010, there were 17.6 million company cars registered in the European Union, which is roughly 7% of the total cars registered in the EU (Copenhagen Economics, 2009; Mock, 2013).

“Company cars determine to a large extent the composition of the entire passenger car fleet in Europe and consequently transport-related CO_2-emissions” (Koetse, 2014, p. 280). This is caused by the fact that 50% of the newly registered cars are company cars, and these cars are sold at the second hand market after 2-5 years. However, company car buyers generally do not consider the entire fuel cost and CO_2 emission over the entire life of the vehicle (Kågeson, 2005). A larger percentage of company cars in the total EU car fleet can therefore result in an increase in the number of cars that have bad fuel efficiency and are more polluting. Moreover, company car drivers often travel in their car alone (Rye, 1999), resulting in more CO_2 emission and fuel usage per transported person. An increasing number of company cars might therefore not be beneficial to the environment.

A large company car fleet is also undesirable for business owners. Large companies that provide their employees with their own company car need to manage a large company car fleet (Saunders & Kirk, 1985; The Finance Director, 2012). A large company car fleet comes with a large price tag. For example, the Dutch Capgemini branch spends 40 million (or 5% of its yearly revenue) on 3000 company cars (Knol, 2015). The management of a large car fleet represents a significant administrative activity (Saunders & Kirk, 1985). It can be debated whether these large investments are justifiable. A lot of Capgemini company cars are only used for commuting. This means that during the daytime, these cars are mostly parked at the office or at a customer. This might not be the most efficient use of their company cars. Car fleet operating companies are also increasingly exposed to environmental criticism. As a direct result of this criticism, companies are developing measures to decrease CO_2 emissions and fuel consumption of their car fleets [2](Vogt, 2014). Reducing the company car kilometres by using the available cars more efficiently and taking advantage of alternative transport modes can be beneficial from a cost and environmental perspective. However, as long as a company provides more or less “free”[3] cars and fuel to its employees, employees are unlikely to be persuaded to start car sharing, or using alternative transport modes (Rye, 1999; Kingham, Dickinson, & Copsey, 2001). In order to motivate employees to use their company cars more efficiently, standard company car policy of providing each eligible employee with its own company car might have to change (see also appendix A: Change management). However, convincing senior management about the importance of travel and about the potential benefits of a different more efficient travel management programme can be hard (Gustafson, 2012).

FIGURE 2 COMPANY CARS ARE PARKED MOST OF THE TIME

[2] In order to promote more sustainable travel, Capgemini is already offering their employees the possibility to travel for business using public transport.

[3] Since a company car is regarded as a benefit to the employee, workers who receive company cars are required in The Netherlands to pay income tax on the equivalent monetary benefit attached to the car (Cohen-Blankshtain, 2008).

1.3 RESEARCH OBJECTIVES AND QUESTIONS

Instead of facilitating employees with their own car, the travel needs of employees should be facilitated. Coffey (2012) discussed servitization of the auto industry. He stated that car manufactures should start “to sell mobility not cars”. The same principle could be applied to the company car. If it is assumed that the only purpose of the company car is to transport an employee, then instead of providing eligible employees with a company car, eligible employees could also be guaranteed a transport possibility by the employer. This transport possibility could be in the form of an own car, but it could also be a car shared with someone going in the same direction, or transportation via public transport or bicycle. By providing mobility instead of company cars, the company car kilometres could potentially be reduced (depending on the individual company and its car usage). To expound the difference between offering lease cars and offering mobility, the mobility policy of Capgemini is compared to a mobility policy where employees are guaranteed a transport possibility instead of having their own car:

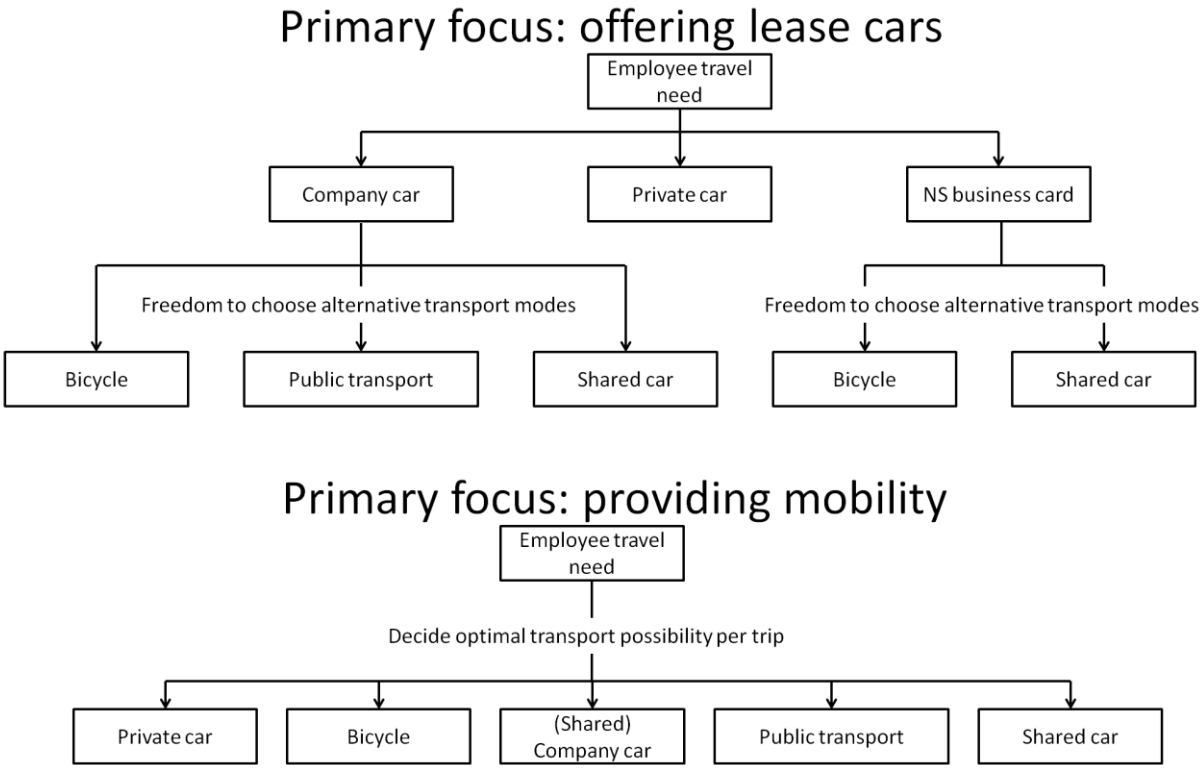

FIGURE 3 COMPARISON BETWEEN CURRENT MOBILITY SCHEME OF CAPGEMINI AND A MOBILITY SCHEME THAT FOCUSES ON OFFERING MOBILITY SOLUTIONS INSTEAD OF CARS.

On the surface, it seems that Capgemini is already providing mobility to its employees instead of cars. However, this is not (entirely) the case. There exist only three options for the employee: Using a company car, using a private car, or using the public transport network. Employees that only use public transport have very limited access to a temporary car (three cars are available; these cars need to be parked at Capgemini Leidsche Rijn at night, and only a handful of employees know of their existence). An employee that has its own lease car can choose to use the public transport instead. However, he still needs to pay for the lease contract each month, whether he uses the car or not. An employee that primarily uses public transport has a problem when he/she often needs to travel to a location that is poorly accessible by public transport because only limited cars are available for temporary use. Employees using their private car for business travels can also use public transport. The incurred travel costs are reimbursed per kilometre travelled, thus the choice of travel mode for employees with an own car are employee specific (and not financially encouraged by Capgemini). Carpooling, and using alternative transport modes that result in a net benefit for both employee and employer are not encouraged in the current scheme.

By focusing on providing mobility instead of cars, flexible use of transport modes during the day is possible. For each travel need, an assessment is made of the optimal method of transportation. Company cars are available when alternative methods of transportation are not feasible. The current Capgemini lease scheme provides employees with a lease car, unless an employee chooses otherwise. When providing mobility instead of cars, the norm becomes to provide employees with a transport possibility not with a lease car. However, before changing company policy to provide mobility instead of cars, first the feasibility and expected benefit of changing the way employee travel needs are satisfied should be studied.

Companies with a large car fleet usually register the business related travels of their employees for billing purposes. Thus travel data of employees is often available for these companies. This data can also be used to discover the opportunities and expected benefits of changing the company policy (focussing more on offering mobility and less on providing cars). Ideally, a tool would exist that uses the already collected travel data of employees and translates this into recommendations for more efficient transport. This tool could then be used to review business' mobility policies and possibly start a platform where ad hoc personalized transport possibilities are offered to employees. As a first step in the development of this tool, this study analyses the travel patterns of company car users which are then used to discover and value the 'big wins'[4] of changing the way travel needs are satisfied.

A method for analyzing travel patterns of company car users is developed using an example case (case study, appendix B). The Dutch branch of Capgemini has provided their (anonymized) employee travel data. This travel data will be used to discover the opportunities and expected benefits of switching from providing cars to a more mobility facilitating company policy for the Dutch Capgemini branch.

RESEARCH GOAL

Discover the opportunities and expected benefit of changing the Capgemini (Dutch branch) company policy of providing company cars to facilitating employee mobility using the already collected employee travel data.

RESEARCH QUESTIONS

Main question: *What business travel improvements opportunities can be discovered for the Dutch Capgemini branch using the employee travel data that is already collected for billing purposes?*

Sub questions:

1. *What employee travel patterns can be found in the Capgemini (Dutch branch) employee travel data?*
2. *How can the employee travel data be used to improve Capgemini's (Dutch branch) business transport of employees?*
    - *What are the expected benefits of the business transport improvements?*
    - *What are the tradeoffs of the business transport improvements?*

DEFINITIONS OF CONCEPTS

Travel need: The perceived need of an employee to physically be at a location different than its current location for business purposes (or to get home after a business visit).

Employee travel patterns: The transport by company car of employees for business purposes. Travel patterns are defined by aggregated origin, destination, timing and recurrence of journeys made by the registered company car fleet of the Dutch Capgemini branch.

Facilitating employee mobility: Guarantying the satisfaction of employee travel needs. This can for example be done by offering the employee an own lease car, a shared car, a carpool possibility, giving them access to the public transport network, or providing them with a bicycle.

More efficient car usage: Having more than one employee use the company car (simultaneously).

[4] The 'big wins' are defined here as the improvement of employee travels that covers simple mobility policy changes (car sharing, using public transport, taking the bicycle) that are expected to result in substantial financial and environmental benefits.

Improve employee business transport: Transporting the same number of employees (assuming no change in transport demand) by driving less lease car kilometres, without costing significantly more money or without resulting in more greenhouse gas emissions[5].

Expected benefit: The financial and environmental gains expected as the direct result of employee business transport improvements. Financial gains are achieved by a reduction in car lease and fuel costs (offset by the costs of the alternate transport mode). Environmental gains are realized by a reduction of the total CO_2 exuded by the lease cars.

Tradeoffs: The negative collateral effects of changing the way employee travel needs are satisfied. Assuming it's possible to reduce the kilometres driven using the lease cars, then this could affect the employee business travel experience. For example: personal property of the employee cannot be left in their car anymore because the cars are shared or the employee travel possibilities are affected by external forces (e.g. taking the train, or carpooling) (see also Appendix C: Company car functionality).

SCOPE

The scope of this study is limited by a number of factors.

- The research is limited to the employees of the Dutch Capgemini branch because Capgemini represents a company with a large lease car fleet and data from Capgemini is available.
- As mentioned previously, the company car can also be used for personal trips. The lengths of these trips are registered, but not their origin and destination. For this research, the private company car travels are not taken into account (this data was not available for this research because of privacy concerns).
- Motivating employees to change their travel behaviour has already been studied (Kingham, Dickinson, & Copsey, 2001). Therefore, this study will not focus on the Capgemini employee willingness to change their travel behaviour, but instead focus on the logistic possibilities of more efficient satisfaction of employee travel needs. A small review about employee willingness to change transport mode is given in appendix D.

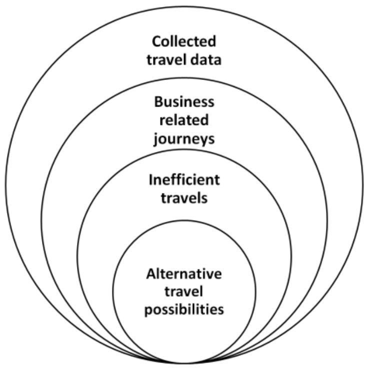

FIGURE 4 VENN DIAGRAM SHOWING THAT ONLY PART OF THE TOTAL LEASE CAR FLEET TRIPS CAN POSSIBLY BE IMPROVED.

1.4 METHODOLOGY

INTRODUCTION

In order to answer the research questions, analyses are performed following the methodology presented below. By performing the analyses described in the methodology, the employee travel patterns are uncovered and more efficient methods to satisfy the employee travel needs are found.

GEOGRAPHICAL INDEPENDENT DATA ANALYSIS

In order to answer research question 1, the patterns in the employee travel data need to be explored. Two types of analyses are performed: analyses on the geographical location of the cars, and geographical independent anal-

[5] Ideally, changing the way employee travel need is satisfied results in both a financial and environmental benefit. However, it is conceivable that a large benefit in one of the two criteria compensates a small loss in the other.

yses. Geographical data analysis requires a geographical information system. However, a lot of information about the travel patterns can be uncovered before a geographical information system is deployed. The timings, origins, destinations, and the time lease cars are parked are analyzed in order to conclude whether the company cars are primarily used for commuting or non-commuting business trips. Analyses of the days the lease cars are used will also reveal whether lease cars are used every day of the week or if some days the lease car is used less. This will also give insight in what days of the week employees in general take a day off. By analyzing the distributions of trip velocity and duration, a preliminary estimation can be made whether the trips can also be performed using a different transport mode.

GEOGRAPHICAL DEPENDENT DATA ANALYSIS

Analyses on the location of the lease cars are more complicated to perform because the location of the cars in our world need to be determined. The location of the cars in the world is done by linking the lease car dataset with other public datasets like a table that converts postcodes into GPS coordinates. Using these GPS coordinates an animation is made to show the location of the cars on a map for each time of day. This animation is then used to gain insight into in what direction the separate lease cars travel during the day. More time independent information about the lease car travel patterns is gathered by plotting the time averaged lease car travel routes. Other information that is extracted from the lease car dataset: Country in which the lease car trips are performed, number of unique locations visited by the lease cars and the frequency of the visits, parking locations of the lease cars over time, and the number of lease car visits to Capgemini offices. Using this information a general impression about the lease car usage is obtained, answering research question 1.

TRAVEL IMPROVEMENT OPPORTUNITIES

Using the travel patterns, improvements for satisfying the employee travel needs are explored. A number of changes will be considered: Carpooling, using the train instead of the car, travelling by bicycle instead of by car, encouraging employees to work at the nearest Capgemini office and using the shared lease car pool more efficiently. These opportunities for changing travel needs satisfaction are chosen because it is expected that these opportunities will result in the largest benefits for Capgemini[6]. For the five opportunities it is analysed how many lease car trips can be changed using this opportunity and what reduction in lease car kilometres can be expected when applying the opportunity.

Quantifying benefits of improvements

If a set of possible travel improvements are found, the benefits of these improvements are quantified. Quantifications focus on the lower carbon emission and financial benefits. The reduction in driven kilometres can easily be related to lowered carbon emission using indices (European Enviroment Agency, 2015; Knol, 2015). Using the same method, the added carbon emission due to using public transport is also easily found (Carbonfootprint, 2015; AMT, 2015; NS, 2016). Financial benefits consist of cost reduction due to the decrease in kilometres driven by lease car (depreciation costs and fuel costs). These need to be offset by the additional costs due to usage of an alternative transport mode (e.g. public transport costs).

Qualitative analysis of tradeoffs

The tradeoffs of the business travel improvements are qualitatively discussed. Based on the found improvement opportunities, the change in ease of travel is discussed from the view point of the affected employee and from the view point of Capgemini.

Performing all above described actions will answer research question 2 (including the sub-questions).

OFFERING MOBILITY SOLUTIONS AND EASE OF IMPLEMENTATION ELSEWHERE

When the benefits and tradeoffs of changing the way travel needs are satisfied, are know, an assessment is made whether it is beneficial for Capgemini to switch from offering lease cars to its employees to offering mobility solutions to its employees. The results of the research are also put in a broader scope by assessing the replicability of the lease car data analysis at other companies using the method applied in this study.

[6] The opportunities for changing the way employee travel needs are satisfied, are chosen in collaboration with the Director Facilities at Capgemini, Jack Knol.

1.5 Report outline

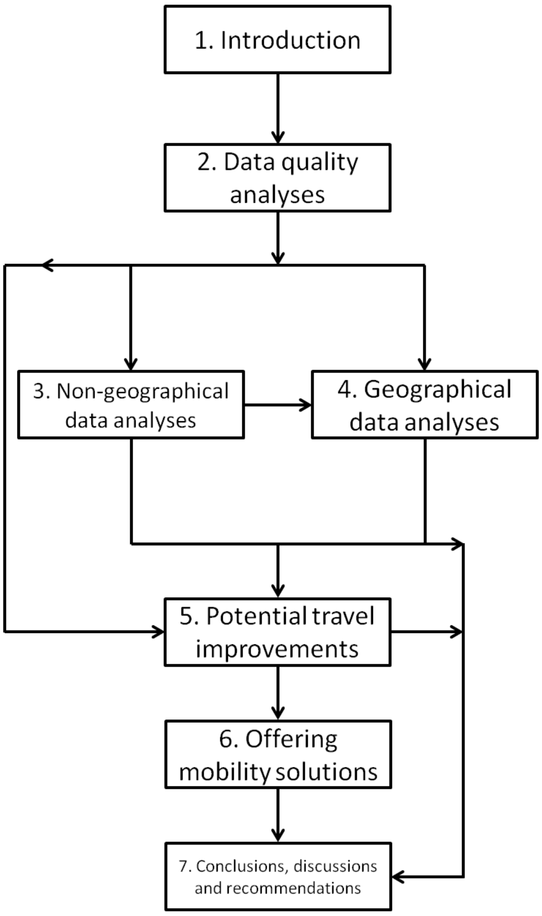

FIGURE 5 VISUALISATION OF REPORT OUTLINE

The next chapter (Ch. 2) will analyse the quality of the lease car travel data to make sure the provided data represent realistic car trips. After removing faulty data entries, the quality checked dataset is used to perform the non-geographical (Ch. 3) and geographical data analyses (Ch. 4). In chapter 4 the lease car travel patterns are described using the results of the previous analyses. The quality checked dataset is then used in combination with the knowledge gathered by analysing the employee travel patterns (Ch. 3 & 4) to find and value potential travel improvements (Ch. 5). Next, the feasibility of offering mobility solutions instead of cars and the feasibility of performing this study at different companies are discussed (Ch. 6). Finally, the answers to the research questions are summarized to conclude this research (Ch. 7).

2. DATA QUALITY ANALYSES

2.1 INTRODUCTION

Before travel patterns are analysed, first the data is analysed to check its quality. The quality check will make sure the provided data represent realistic car trips. The data quality analyses will indentify trips and/or cars that are not suitable for further analyses. A sub selection of the available data to be used for all subsequent analyses is then made based on the data quality analyses. First, an introduction is given of the Capgemini business travel compensation scheme because the used data is collected by Capgemini to facilitate their business travel compensation scheme.

2.2 CAPGEMINI BUSINESS TRAVEL COMPENSATION SCHEME

Depending on your function, Capgemini awards its employees with a certain mobility budget. This budget is "freely" useable to buy your mobility solutions. The part of the budget that remains unused is kept by the employee as additional income (after paying taxes). When public transport is chosen as the main travel possibility, the costs incurred while travelling are subtracted from the gross salary. Alternatively, a car can be leased (full operational lease). The cost of the contract is then subtracted from the employee's gross salary. Employees with a lease contract operate under a bonus-malus system, where driving less and more fuel efficient and buying cheaper gas from stations not located near highways is promoted. Finally, the employees can travel by their own car (or bicycle), compensation of travel costs is based on the number of driven kilometres in that case. The entire mobility budget is always added to the employee's salary (taxes need to be paid). The incurred travel costs are subtracted from the employee gross salary. Following this scheme, the employee does not pay income tax on their travel expenses.

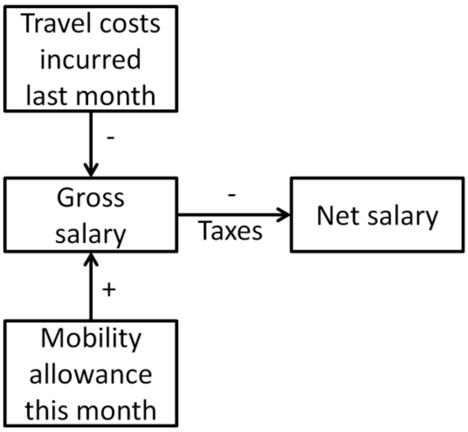

FIGURE 6 VISUALISATION OF CAPGEMINI MOBILITY COMPENSATION SCHEME.

2.3 AVAILABLE DATA DESCRIPTION

In order to correctly process the travel expenses of its employees, a number of systems are used by Capgemini to collect the necessary data. Capgemini gets an invoice about the incurred expenses of the public transport trips of its employees as part of the NS business card service (unavailable to this study) (NS, 2015). In order to monitor the usage of the lease cars, Capgemini hired the services of Mobility Concept (2015). Mobility Concept (2015) provides a platform where both employers and employees can keep track of their car usage. On this platform, employees can directly see the effects of their travel patterns on their mobility budget. Employers can use the same platform to get aggregated data about their car fleet usage and to pass car usage information down to administration. In order to gather car usage data, Mobility Concept installed board computers on the entire car fleet of Capgemini. This board computer contains a switch that registered whether the current trip should be classified as business or personal travels. The data collected by the board computers installed by Mobility Concept are analysed in this thesis.

Eight months of trip data (January 2015 up to August 2015) are available. During this time period 542,651 individually trips were registered. A total of 1,729 unique cars were active during this time, used by 1,765 different employees. The difference between the number of cars and number of employees is caused by employees leaving Capgemini. Their lease cars are then used by a new willing employee after some time. Each time a car was started, the board computer registered data from a number of sensors. This data is contained in the following variables:

Variable	Description
License plate	Unique number identifying the cars
Source of data	Data either came from the web service, or was entered manually when no data about the trip was registered by the web service
Type of car	This column states “lease car” for each data entry.
Departure date	Date and time of departure
Departure address	Street name and house number of departure location
Departure house number	Redundant variable that does not contain any values
Departure postcode	Postcode of departure location
Departure city	City of departure location
Departure country	Country of departure location, given in three letter abbreviations
Departure description	Description of departure location. This variable is actually used to indicate peculiarities of the data entry. The entire dataset only contained three unique values for this variable. The variable was either left empty, the variable explained that this specific data entry represents a trip not registered by the automatic system, or the variable explains that the trip represents a correction on the travelled kilometres due to a mismatch between mileage and actual travelled kilometres.
Arrival date	Date and time of arrival
Arrival address	Street name and house number of arrival location
Arrival house number	Redundant variable that does not contain any values
Arrival postcode	Postcode of arrival location
Arrival city	City of arrival location
Arrival country	Country of arrival location, given in three letter abbreviations
Arrival description	Empty variable
Distance travelled	Estimation of travelled kilometres based on the registered car mileage
Detour kilometres	Number of kilometres detour from origin to destination
Start mileage	Odometer reading at the start of the trip
End mileage	Odometer reading at the end of the trip
Type of travel	This variable equals "business" for each data entry. Most likely there is also data about personal trip, but this data was not available to this study.
Status	This variable equals "exported to payroll" for each data entry. This means every data entry is the dataset has been sent to the payroll administration
Last status change	Date and time of last change to the data entry

TABLE 1 DESCRIPTION OF DATASET VARIABLES

A number of peculiarities are noticed. Some variables are empty (Arrival description) or redundant (house number). Moreover, some variables (Departure description) are used for remarks other than what the name of the variable implies. It seems that the collected dataset is adjusted to the specific needs of Capgemini, which resulted in a slight mismatch between meta data and actual data. However, this mismatch does not decrease to usability of the available dataset for this study.

2.4 DATA QUALITY ANALYSES APPROACH

Now that it is clear what data is available, the quality of the data is analysed. The registered trip data does not necessarily accurately represent the actual travels performed. In order to perform the study on data representing realistic trips, five quality checks are performed on the entire dataset:

1. Checks on empty variables
2. Checks on trips with negative travel time or distance
3. Checks on trips with zero travel time or distance
4. Checks on trips with very slow or fast average travel speeds
5. Checks on very short or long trips (in time and space)

Based on these checks, 3.5% of all trips are flagged as unrealistic or unusable for further analyses.

2.5 DATA QUALITY ANALYSES RESULTS

<u>1. Empty variables</u>
Less than 1.5% of the individual trips contain one or more empty (missing) variables. Trips that contain no location data are excluded from the analyses in the following chapters. This means 98.5% of the dataset is suitable for further analyses based on the missing data criteria.

<u>2. Negative travel time/distance</u>
Only 28 trips contain a negative travel time or distance. These trips are deleted from the dataset because they defy the laws of reality.

<u>3. Zero travel time/distance</u>
Roughly 3% of the trips contained zero travel time, distance or both. Trips with zero travel time/distance are either unrealistic (in the case of zero travel time/distance in combination with positive travel distance/time) or useless (in the case of both zero travel time and distance). These trips are removed from the dataset.

<u>4. Average travel speed</u>
1% of trips travelled less than 1 km with an average speed of 5 km/h. Travelling over those distances, walking would be a (more) viable alternative to using the car, thus taking the car might not have been worth the effort. It is therefore questioned whether these trips have actually occurred or if the trips are in fact artefacts. However, because these short and slow trips could potentially have occurred, they are left in the dataset.

239 trips have an average travel speed larger than 150 km/h. Most of these trips only travelled over a small distance (<2 km). Because it very hard to reach an average speed of 150 km/h over 2 km, these trips are deemed unrealistic and therefore deleted.

<u>5. Unrealistically short or long trips</u>
No trips are found that are deemed unrealistic based on their travel duration or distance, except for the zero travel time/distance trips discussed previously.

A more extensive description of the data quality analyses is given in appendix E

2.6 DATA SELECTION

Using the analyses described above, the available data is filtered, removing any unrealistic data entries. Trips that were classified as system rectification are removed from the dataset. The same goes for trips that report negative or zero distance or time travelled. Trips with an average velocity faster than 150 km/hour are also removed from the dataset. Lastly, trips that do not contain any information (list entry 1: *Empty variables*) about either origin or destination are also removed from the dataset. This is done because future analyses need information about the destination and origin of trips. Out of the 542,651 trips, 19,039 or roughly 3.5% of the total dataset are deemed unsuitable for further analyses.

3. NON-GEOGRAPHICAL DATA ANALYSES

3.1 INTRODUCTION

Using the filtered dataset, an initial analysis is performed to discover employee travel patterns. This chapter will focus on all non-geographical analyses like travel timings, average travels per day, average distances travelled and more. These analyses will result in a provisional description about Capgemini lease car fleet usage. In the next chapter the origin/destination patterns of business travels are discussed.

3.2 NON-GEOGRAPHICAL DATA ANALYSES APPROACH

Two types of analyses are presented in this chapter. First a number of aggregated statistics are presented. Statistics like the average travelled kilometres per trip or average travel time per day are discussed. These statistics will give an overview of the average trip performed by a Capgemini lease car. Because averages do not always represent a dataset correctly, the distribution of a number of trip related variables are also analysed. Special attention is given to the time that a car is not moving for business purposes. These 'parked times'[7] are interesting to analyse because a 'parked' car has the potential to be used to satisfy another employees' travel need. The distribution of the trip lengths are studied in order to discover the average length that an employee travels. Similarly, the distribution of travel time is used to get insight into the average travel times of the employees. Finally, the timing of the trips are analysed in order to determine the time of day/week that the cars are used. Using the averaged statistics and variable distributions, provisional conclusions are drawn about the lease car usage patterns.

3.3 NON-GEOGRAPHICAL DATA ANALYSES RESULTS

AGGREGATED DATASET STATISTICS

In table 2, a number of aggregated dataset statistics are presented. Their implications are discussed below.

The filtered dataset consists of 533,612 trips that were registered during a period of 242 days. 1,729 unique cars are contained within the dataset. This is less than the 3,000 reported in chapter 1. This difference is caused by the fact that not all lease cars are outfitted with a location tracking device (yet). Only the cars with location tracking are contained within the dataset.

On a work day, on average 75 km is driven with a lease car. This distance is covered in 64 minutes. However, these numbers might not represent an average work day. The average travelled distance per day is not equal to twice the average trip distance. Assuming that most employees use (among other things) the car for commuting, then these results indicate that some employees do not use their car every work day. This is also reflected by the fact that less than 2 trips are made per work day per car. When the car is used for commuting every day it is expected that this number is larger than 2. However, employees working part time, or using public transport now and then can lower this number to below 2.

The average distance and time travelled per trip is perhaps a better indicator for average lease car usage because this variable does not take into account days where the car is not used. On an average trip, the company car is used for 37 minutes to travel 44 kilometres. This gives an average speed of 71 km/hour. These are travel speeds that are within the margins of train transport (average speed of train is 100-120 km/hour excluding waiting time at the stations gemiddeldgezien.nl, 2015). It is hypothesized that the average trip by lease car could potentially be performed in roughly the same time by train (on average, neglecting the locations of train stations). In the coming chapters this hypothesis is explored further.

[7] 'Parked' time is put in quotations because it is possible that the car is used for personal travel needs during the 'parked' time.

Usage statistic	Value	Description
Total realistic trips	523,612	Number of trips used for analyses after removing erroneous trips
Unique cars	1,729	Number of unique cars driven during the time period of the available data
Start dataset	01-01-2015	Date of first trip entry
End dataset	31-8-2015	Date of last trip entry
Number of days in dataset	242 days	Number of days between first and last trip entry
Total kilometres travelled	22,829,934 km	Total kilometres travelled by the entire lease car fleet between the start and end of the dataset.
Total travel time	13,547 days	Total days travel time by the entire lease car fleet between the start and end of the dataset.
Average number of trips per work day	2,981	Total number of trips performed on an average work day by the whole Cagemini fleet
Average number of trips per weekend day	156	Total number of trips performed on an average weekend day by the whole Cagemini fleet
Average number of trips per work day per car	1.72	-
Average number of trips per weekend day per car	0.15	-
Average travelled distance per work day	75 km	Total number of kilometres travelled per car averaged over all work days
Average travelled distance per work day trip	44 km	Kilometres travelled per car averaged over all work day trips
Average travelled distance per weekend day	4 km	Total number of kilometres travelled per car averaged over all weekend days
Average travelled distance per weekend day trip	42 km	Kilometres travelled per car averaged over all weekend day trips
Average travel time per work day	64 min	Total number of minutes travelled per car averaged over all work days
Average travel time per work day trip	37 min	Minutes travelled per car averaged over all work day trips
Average travel time per weekend day	3 min	Total number of minutes travelled per car averaged over all weekend days
Average travel time per weekend day trip	32 min	Minutes travelled per car averaged over all weekend day trips

TABLE 2 AGGREGATED DATASET STATISTICS

Most trips are performed during work days (1.72 trips/day/car during work days versus only 0.15 trips/day/car during weekend). The averaged travelled kilometres during work days are almost 19 times larger than the averaged travelled kilometres during weekends. It can be concluded that the business car is only very little used during weekends (for business). Note that the average distance travelled for a trip during the weekend is almost equal to the average distance travelled for a trip during a work day. Thus when travelling for business during the weekends, the trip itself is very similar to trips performed during work days.

Analyses of the mean statistics results in the following conclusions:

- The average distance per trip (44 km) versus the average distance per work day (75 km) and the number of trips per workday (< 2) all indicate that the company car is not used every work day.
- Employees travel on average 44 kilometre per work day trip with an average speed of 71 km/hour. These distances and speeds might also be achievable using public transport (trains).
- During work days the lease car is used more often than during weekend days, but when used during the weekends, the trip itself is of similar length and duration as a work day trip.

Distribution of 'parked time' between trips

The time between two subsequent lease car trips is interesting to evaluate because during this pause the car has the potential to satisfy other employee travel needs. During the 8 months in which data is gathered, the Capgemini cars are not used for business travels 97% of the time[8]. That means that 97% of the time, the lease cars are either parked or driven for private purposes. Beware that these number include weekends, nights and holidays.

[8] Calculated by dividing the total minutes on the road for business by the total minutes in 8 months

Nonetheless, this number shows the potential to use the available cars more intensively. In the coming pages, the usage of the Capgemini lease car fleet is more thoroughly analysed.

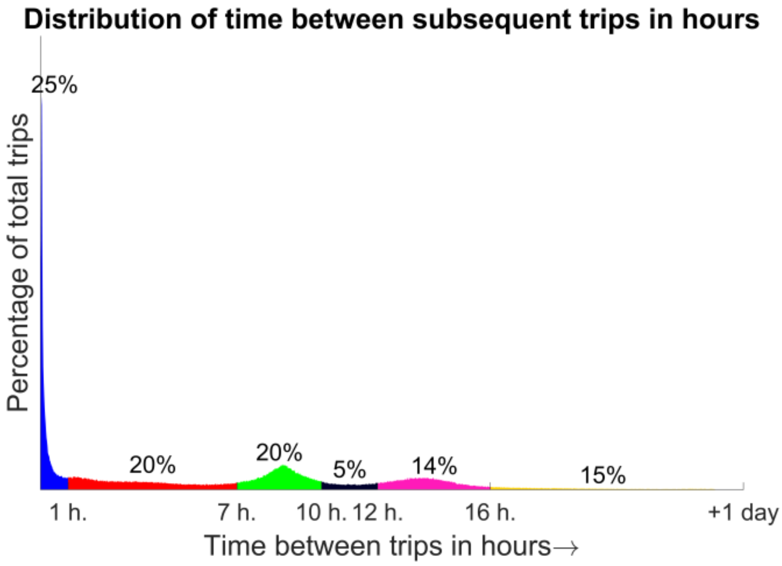

FIGURE 7 DISTRIBUTION OF TIME IN BETWEEN SUBSEQUENT TRIPS. PERCENTAGES ABOVE THE FIGURE REPRESENT THE NUMBER OF TRIPS IN THE COLORED AREA OF THE GRAPH.

Figure 7 shows the distribution of time in between two subsequent trips with the same car. This distribution will give an idea about how the Capgemini car is used in time. Three peaks are noticed in the above figure. A large peak for ‘parking times’ smaller than 30 minutes, a peak at roughly 8 hours of ‘parking time’, and a peak at roughly 14 hours of ‘parking time’. The peaks at 8 hours and 14 hours most likely represent standard employee commuting. The green area represents the ‘parking time’ at work and the pink area represent the ‘parking time’ at home. The blue peak is interesting. This peak represents less than 60 minutes between two subsequent trips. The largest part of the blue peak is located between ‘parking time’ of 1 up to 15 minutes. The question arises whether the car was actually ‘parked’ in between those two trips, or if the ‘parking time’ of less than 15 minute is actually an incorrect registration of the onboard computer? This issue is discussed further.

The onboard computer ends the trip when the engine of the car is turned off. In general turning off the engine indicates that the destination is indeed reached. However, the engine can also be shut down when the destination had not yet been reached. For example, when filling up the car at a gas station or taking a bathroom or lunch break, the engine also needs to be turned off. The computer will register this as two separate trips, one before reaching the gas station, and one after reaching the gas station. In reality, these two trips are most likely part of a single travel action. Of all trips, 98,053 trips were followed by a new trip using the same car within 15 minutes of arrival at the first destination. This is roughly 18% of all trips registered. However, considering that buying gas is an activity that is frequently performed, 18% is not unlikely. It is assumed for this study that subsequent trips with only 15 minutes in between are in fact part of the same travel need. Linking these trips together will better represent the actual travels as performed by the employees.

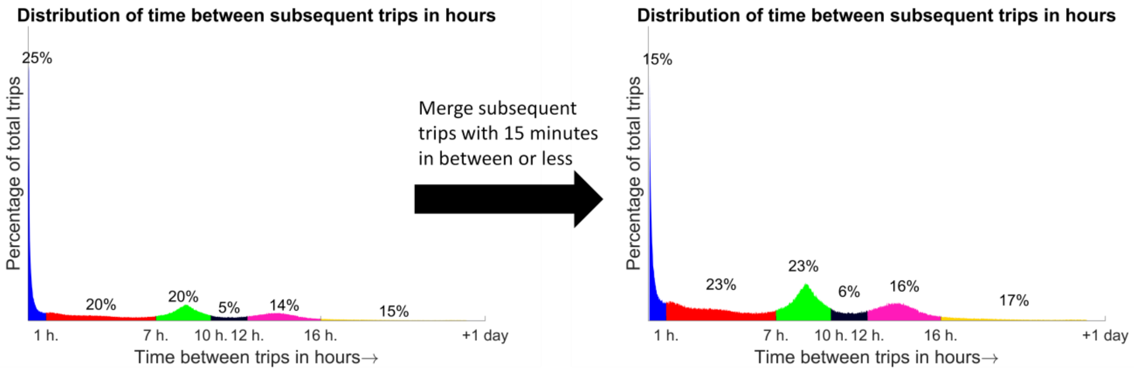

FIGURE 8 COMPARISON OF DISTRIBUTION OF 'PARKED' TIME INCLUDING 15 MINUTE OR LESS 'PARKING' TIMES (LEFT) AND AFTER MERGING (RIGHT) TRIPS WITH LESS THAN 15 MINUTES OF TIME BETWEEN THEM. PERCENTAGES ABOVE THE FIGURE REPRESENT THE NUMBER OF TRIPS IN THE COLORED AREA OF THE GRAPH.

Figure 8 compares the distribution of time between trips when 15 minute trips are merged (right) or not (left). By merging the trips, the other time categories include more trip instances. Clearer peaks emerge at the 'parked' at work (green) and 'parked' at home (purple) time slots. The red zone is also filled more. The red zone represents lease cars that are used for more than just commuting, resulting in a lot of trips with 1 to 7 hours in between trips.

In the right graph of figure 8 the blue area still contains a large peak. The threshold for trips that are merged is set at 15 minutes pause between trips. However, it is possible that trips were interrupted for 16 minutes, resulting in the peak shown in the figure above. The alternative is also possible, two actual separate trips with 15 minutes in between that were merged erroneously (very short meeting at a location). It is unknown whether the trips are actually part of a single travel need or not. The threshold of 15 minutes is upheld because it is expected that 15 minutes is a reasonable time for trip pausing activities to be performed (tanking, toilet visits etc.). Increasing this margin will result in more trips erroneously being merged. Decreasing this margin results in more trips erroneously not being merged.

The yellow part in figure 8 represents 'parking times' longer than 16 hours, enlarging this section results in the following graph:

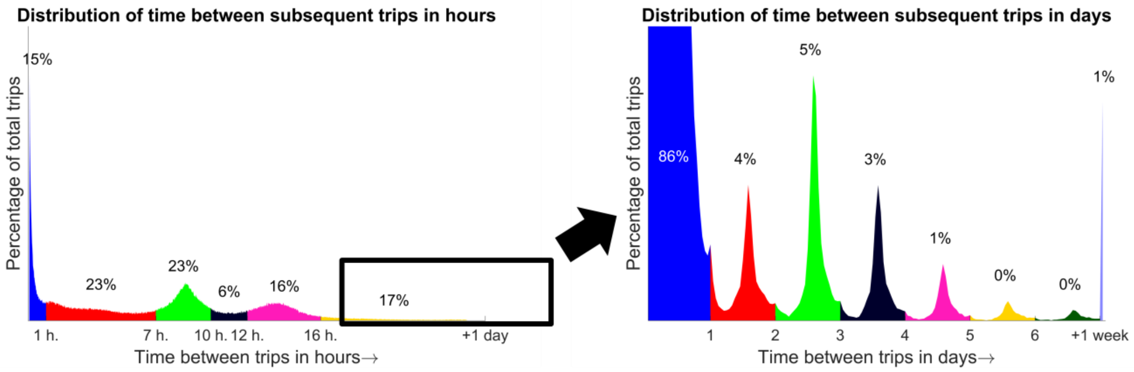

FIGURE 9 TIME IN BETWEEN BUSINESS TRIPS LONGER THAN 16 HOURS. THE PEAK AT THE RIGHT EDGE OF THE FIGURE IS CAUSED BY THE SUMMATION OF ALL 'PARKED TIMES' LARGER THAN 1 WEEK (CHANGE IN PERCENTAGES DUE TO ROUNDING). PERCENTAGES ABOVE THE FIGURE REPRESENT THE NUMBER OF TRIPS IN THE COLORED AREA OF THE GRAPH.

When only considering pause in between trips longer than 16 hours, three peaks in particular are noticed: pauses of roughly one(red) two (green) and three (dark blue) days. In order to classify these 'parking times', the day of the week when the 'parking' started is visualized for the 'parking times' of one, two, and three days of 'parking time'.

FIGURE 10 GRAPH DEPICTING ON WHAT DAY CARS ARE USUALLY 'PARKED' FOR ONE, TWO OR THREE DAYS.

Figure 10 shows that when cars are 'parked' for two or three days, the first day of 'parking' is (the end of) either Thursday or Friday. This is most likely the result of employees who have a two, or three days weekend (starting Thursday/Friday evening). However, it is also possible that employees use alternative transport to work more often on Fridays resulting in a 'parking time' of three days. Finally, employees who work at home on Fridays will also result in 'parking time' of three days. When a car is 'parked' for one day, this usually occurs at the beginning of the week. The reason for this is quite simple. The chance of a car being 'parked' for only one day becomes smaller and smaller when nearing the weekend. An explanation: Assume that an employee chooses to take the public transport instead of the car on a Friday, this will result in a 'parking time' of three days instead of one because during the weekends the car is also usually not used for business travels.

The following is concluded on the basis of the analyses of the time in between trips:

- In total, the lease cars are driven only little for business. 97% of the time the car is 'parked' somewhere or driven for personal purposes
- Peaks at 8 hours and 14 hours of 'parking time' are most likely caused by 'parking' at work and at home due to commutes.
- Numerous cars have 15 minutes or less between subsequent trips. These trips are most likely part of the same travel need. Merging these trips resulted in larger peaks for the 8 and 14 hour 'parking time'.
- 23% of the trips have between 1 and 7 hours of 'parking time' in between them. This is most likely caused by non-commuting business trips.
- The 'parking time' peak of two days is likely caused by employees who are having a two day weekend.
- 'Parking times' of three days could be caused by employees who use an alternative transport mode on Fridays. It could also be caused by employees who do not work on Fridays or who work at home.
- The analyses of the time in between subsequent trips indicate that employees do leave their car at home from time to time. This could be the result of a deliberate choice to utilize a different transport mode. It could also be the result of a lack of travel need either because the employee has a day off, or works at home. The data shows that there exists a possibility that employees already deliberately chose not to use their lease car.

MAXIMUM 'PARKED' TIME

It is possible that a number of cars in the fleet are only very little driven. Insight into the number of cars that are only driven sparsely is useful because the cars that are only little driven can possibly be used for other purposes. Alternatively, cars that are only very little driven could possibly also be remove from the car fleet. In order to study how much individual cars are driven, the distribution of the maximum time that each car is 'parked' uninterrupted is analysed.

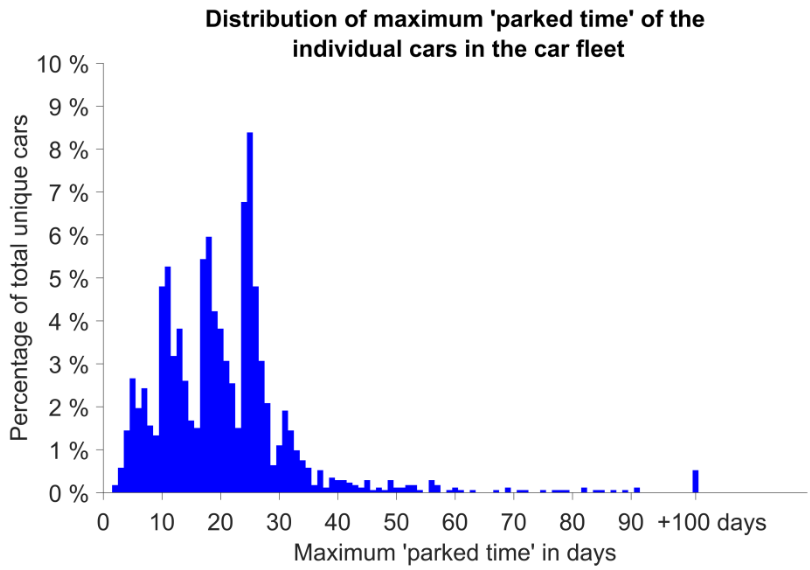

FIGURE 11 DISTRIBUTION OF THE MAXIMUM TIME EACH INDIVIDUAL CAR IS 'PARKED'.

Figure 11 shows the number of days that each individual car is 'parked' uninterrupted. Five peaks are observed in figure 11, at 5-7; 10-11; 17-18; 24-25 and at +100 days. The peaks at 10-11; 17-18 and 24-25 days are easily explained. These peaks correspond to not driving the company car for one, two or three weeks (including two. three or four weekends respectively). These peaks are most likely caused by employees going on holiday. The peak at 5-7 days 'parking time' were a bit harder to classify. Further analyses of the data revealed that when a car is 'parked' for 5 to 7 days, this usually happens on a Wednesday, Thursday, or Friday. A possible explanation for this length of 'parking' is employees taking half a week holiday (including the weekend). The peak at +100 days contains all cars that were 'parked' for more than 100 consecutive days. A total of 9 cars were 'parked' longer than 100 consecutive days before being used again. One car did not move for business purposes for little short of half a year (182 days). A number of reasons exists for explaining cars that are 'parked' for this long. Most likely, the owners of these cars were outsourced to a location that is reached easier using other transportation modes (airplane, public transport, bicycle). Alternatively, it is also possible that an Capgemini employee left the company. The lease car is then not used until a new employee is willing to take over the lease contract.

Fifty percent of all cars in the car fleet were never 'parked' for longer than 19 days. Ninety percent of all cars were never 'parked' for longer than 31 days. This indicates that most of the cars in the Capgemini car fleet are used on a (somewhat) regular basis (taking into account employee vacations). However, figure 11 also shows that there are a number of cars in the Capgemini fleet that perhaps could have been used more effectively ('parking times' of +100 days).

Note that 38 cars were never 'parked' for more than 4 consecutive days. Taking into account national holidays, this could indicate that the employees driving these cars have not taken a single day off during the 242 days contained in the dataset. One might consider sending these employees on a mandatory holiday since it has been stated that taking holidays actually increases yearly productivity (Thompson, 2012). Compared to the size of the total Capgemini fleet (1,729 unique cars), these 38 cars only represent 2% of the total car fleet, thus employees not taking timely holidays does not seem to be a large problem.

Based on the analyses of the maximum 'parked time' the following is concluded:

- When cars are 'parked' for an extended period of consecutive days, then most cars are 'parked' for exactly one or multiple weeks. This makes it likely that these cars are 'parked' because the employee took a holiday.

- A small number of cars (9) is 'parked' for an exceptional long time (+100 days). This is possibly related to employees sent abroad. These cars could potentially be used more effective during this time[9].
- Overall, the car fleet is moving on a regular basis. Ninety percent of the car fleet is never 'parked' for more than 31 consecutive days. This is decent usage percentage considering employee holidays.

DISTRIBUTION OF TRIP LENGTH

Below, the distribution is given of the trip lengths. These trip lengths are calculated after merging trips with 15 minutes in between them (to take into account tanking etc.).

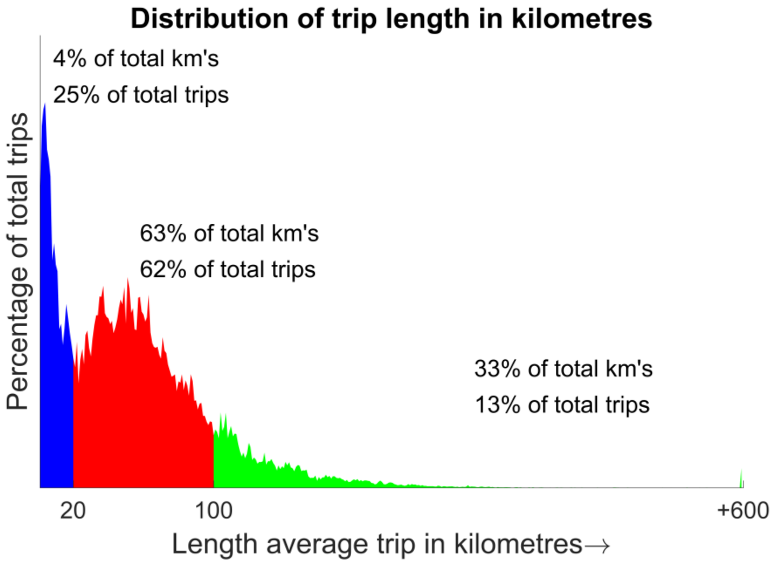

FIGURE 12 DISTRIBUTION OF TRIP LENGTH AFTER SUBSEQUENT TRIPS WITH 15 MINUTES IN BETWEEN ARE MERGED.

The distribution shows that a large number of trips are shorter than 20 km even after merging the 15 minutes 'parking time' trips. In the quality analyses it was discussed that these very short trips might be the result of incorrect registration of a trip by the onboard computer. These trips were left in the database because there was no way to be sure which trips were erroneously registered and which were actually very short business trips. Note that all trips shorter than 20 kilometres combined only account for 4% of the total travelled kilometres. Most trips fall in the 20 to 100 km/trip range. This group is also responsible for most of the total travelled kilometres. Trips longer than 100 km occur much less frequent, but these trips do account for roughly one third of the total travelled kilometres.

Based on the distribution of the trips lengths, the following is concluded:

- Capgemini lease cars are primarily used for short trips and for a number of longer (possibly international) travels.
- A lot of trips shorter than 20 kilometres are made using a lease car. These trips only account for a very small part of the total travelled kilometres.
- Trips with lengths larger than 20 km account for 96% of the total travelled kilometres.

[9] Note that a small part of the lease cars finished their contract. When this happens, the lease car is often sold by the lease company. However, the lease car billing data does not reveal whether a car is parked for a long time, or sold. Therefore, it is expected that a few cars, that the analyses identified as parked for a long time, are in fact removed from the lease car pool.

Distribution of trip duration

The distribution of trip durations are shown in the figure below.

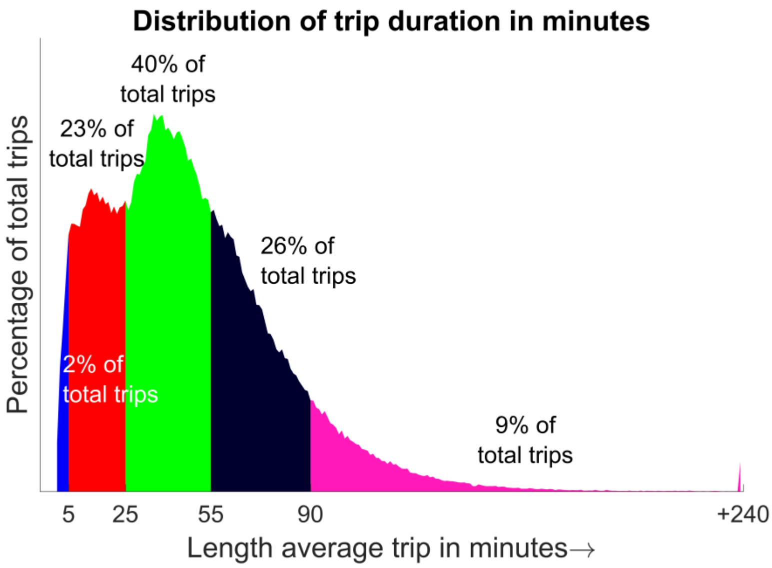

FIGURE 13 DISTRIBUTION OF TRIPS DURATION AFTER SUBSEQUENT TRIPS WITH 15 MINUTES IN BETWEEN ARE MERGED. PERCENTAGES ABOVE THE FIGURE REPRESENT THE NUMBER OF TRIPS IN THE COLORED AREA OF THE GRAPH.

Only little very short (duration) trips are left in the dataset as can be seen in figure 13 (blue area). Most trips take between 5 and 90 minutes (89%) with a clear peak for trips between 25 and 55 minutes. The lease cars are therefore used only in short intervals. The distribution of the duration of the trips in combination with the distribution of the trip lengths (figure 12) paint a picture of lease cars that are not driven for extended periods of time and distances most of the time. Based on this data, the travel needs of the employees can be described as considerable, but relatively small for most trips. Only a very small percentage of the total trips take more than 90 minutes (9%) or travel more than 100 km (13%). This travel need for transportation over small distances (< 100 km) might also be satisfiable using public transport for a number of individual employees. This will be explored more in depth in the coming chapters.

Note that figure 12 shows that a large number of trips that only travelled a short distance are found in the dataset whereas figure 13 shows that only very little trips travel for 5 minutes or less. It is hypothesized that the short trips are trips within a city. Due to city traffic, the average travel speed is low, resulting in a large number of short trips, but not that many trips taking 5 minutes or less.

The following is concluded:

- Lease cars are mostly used for short to middle long trips (<100 km; < 90 minutes).
- This travel need has the potential to also be satisfied using other means of transport beside cars.
- Trips within the city might cause a large number of short trips, but not a large number of trips that travel 5 minutes or less.

TIMING OF TRAVELS

Figure 14 shows the usage of the Capgemini car fleet averaged over all work days for which data was available.

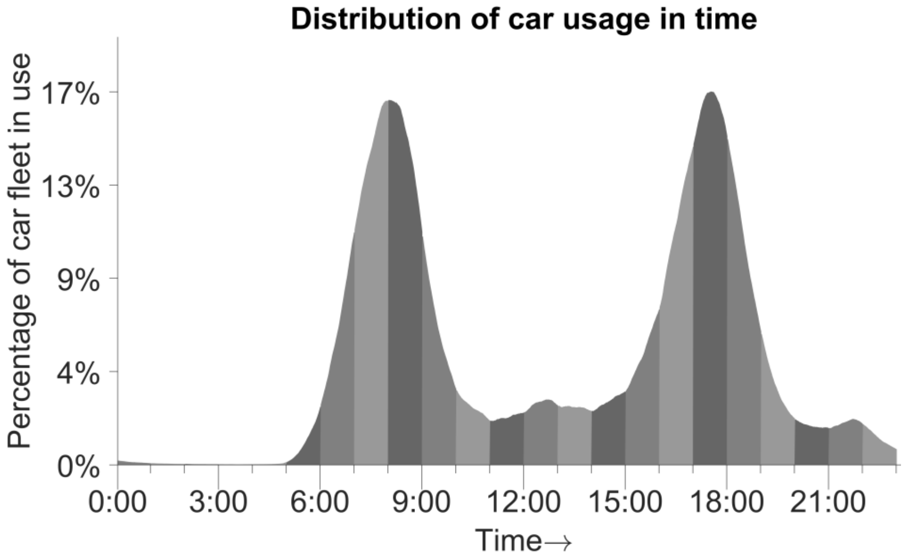

FIGURE 14 PERCENTAGE OF THE CAPGEMINI CAR FLEET ON THE ROAD DURING THE DAY.

A number of things are noticed. First of all, two very clear peaks can be seen at the morning and evening rush hours. This confirms the assumption that the lease car is primarily used to commute. Two much smaller peaks can also be identified at noon and at 22.00. It is hypothesized that a number of employees have appointments at two different locations in the morning and afternoon. Therefore, around noon, a temporary increase in the number of cars on the road is observed. The peak around 22.00 hours is most likely related to the workshops organised by Capgemini, which usually end around 22.00.

Note that even during rush hours, the utilisation of the Capgemini lease car fleet remains lower than 20%. However, figure 14 might give a distorted image of reality in this case. Figure 14 presents the utilisation of the lease car fleet per minute. This means that at the peak of car utilisation, roughly 17% of the Capgemini car fleet is on the road, during that specific minute. Thus, this does not take into account all cars that were driven during rush hour, but who arrived at their destination one minute before the peaks shown in figure 14. Figure 14 is intended to be used primarily to clarify the fluctuations in car usage during the day. Based on figure 14, it is concluded that the bulk of car movements occur during rush hour. However, also note that during day time at any given moment, at least 3% of the Capgemini car fleet is on the road. Thus the employees travel need is ever present during daytime.

Table 3 shows the usage of the Capgemini fleet during and outside of rush hour on work days.

Usage statistic	Value	Description
Usage car fleet during morning rush hour	49%	Percent of the lease car fleet used for business travel during morning rush hour (6.30 to 9.30; ANWB, 2015) on average on a work day.
Usage car fleet during evening rush hour	49%	Percent of the lease car fleet used for business travel during evening rush hour (15.30 to 19.00; ANWB, 2015) on average on a work day.
Usage car fleet outside of rush hour	39%	Percentage of lease car fleet used at any time outside of rush hour on average on a work day.

TABLE 3 PERCENTAGE OF CAR FLEET USED DURING AND OUTSIDE OF RUSH HOUR ON A WORK DAY

Table 3 shows that during morning and evening rush hour, on average, roughly 49% of the entire Capgemini car fleet is used. Thus, the Capgemini car fleet is actually used quite intensively during rush hours. On average 39% of the lease cars are used outside of rush hour during a work day. This indicates that either employees are also commuting outside of rush hour quite a bit, or employees have a business travel need beside commuting which they often satisfy outside of rush hour.

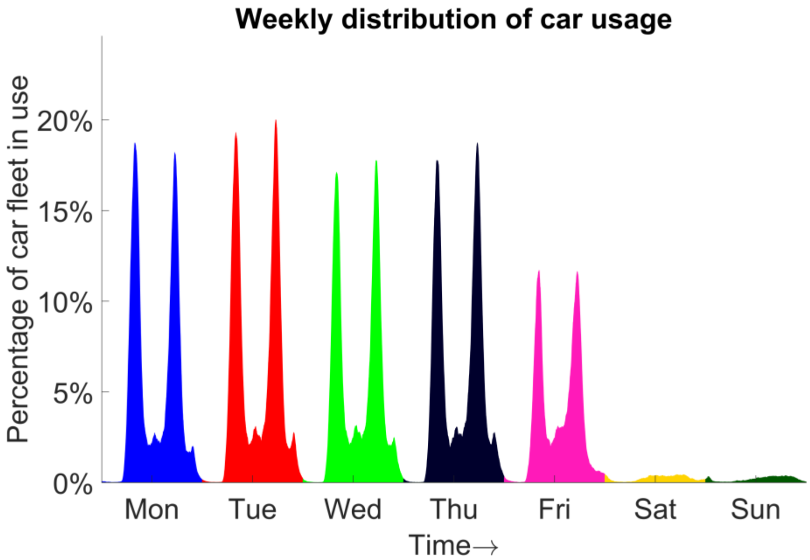

FIGURE 15 DISTRIBUTION OF CAR FLEET USAGE DURING A WEEK.

Figure 15 shows the car fleet usage similar to figure 14 but for the whole week. A clear distinction can be seen between car usage during work days versus car usage during weekends. Notice that car usage is largest during the rush hours on Tuesdays. The car is used noticeably less on Fridays. This is most likely caused by employees who don't work on Fridays, or who work at home on Fridays. Noticeable peaks in car usage are observed on Monday up until Thursday at 22.00 hour. Friday does not contain a peak at 22.00 hour because Capgemini does not organise workshops on Fridays. On Fridays, the car usage after noon is noticeably higher than for the other work days. This is probably caused by employees who go home a bit earlier on Fridays (because they already worked 40+ hours).

Based on the analyses of trip timing, the following is concluded:

- The lease car fleet is most intensively used during rush hour. During rush hour, on average 49% of the entire lease car fleet is on the road.
- Beside rush hour, the car fleet is used more intensively just after lunch and around 22.00 hours. This is most likely related to appointments after lunch at different locations and evening workshops organised by Capgemini.
- During a work day, the car usage percentage does not drop below 3%. This indicates a continual employee travel need during day time.
- On Fridays a clear decrease in car usage is shown, most likely caused by employees working at home or having a day off.

3.4 INITIAL CONCLUSION ABOUT TRAVEL PATTERNS

Based on the non-geographical data analyses a number of things are concluded about the employee travel patterns.

Company cars are primarily used for commuting. During rush hour, on average 50% of the Capgemini car fleet is moving. When a lease car is 'parked', it is often 'parked' for 8 or 14 hours at a time, corresponding to the time 'parked' at work and at home respectively. This strengthens the conclusion that the lease cars are primarily used for commuting.

The lease cars are also used for business trips other than commuting. 23% of subsequent trips have a 'parking time' between 1 and 7 hours. This indicates that during the work day, a reallocation is performed by the employee that’s most likely not part of his commute. Moreover, at any given time during the day, at least 3% of the Capgemini fleet is on the road. This strengthens the hypothesis that the lease cars are also used for business to business trips (in contrast to commuting).

Data analysis revealed that the lease cars are not used every work day. Less than 2 trips per work day are performed on average by the lease car. The ‘parking time’ analyses also revealed that a number of cars are ‘parked’ for either one or three days. This strengthens the proposition that the lease cars are not driven each work day. It remains unclear whether the ‘parked’ cars on weekdays are the result of employee having a day off, or employees utilising other means of transport.

The overall transportations performed by lease cars show potential to be performed using other means of transportation. The average trip using the lease car is 44 kilometres long and has an average speed of 71 km/hour. These are distances and velocities that could potentially also be achieved using for example a train (assuming train stations at convenient locations). Using other means of transport to satisfy the employee travel need is analysed further in the coming chapters.

4. Geographical data analyses

4.1 Introduction

This chapter will focus on the (change in) position of the lease cars during the 8 months for which data is available. Special attention is paid to the number of unique origin/destination combinations of the lease cars, the international travels performed, the parking locations of the cars during business hours and over night, and the cars moving to and from Capgemini offices. The results of the geographical data analyses are combined with the results from chapter 3 to describe the travel patterns of the Capgemini lease car users.

4.2 Geographical data analyses approach

How much unique locations are visited by the Capgemini lease cars? In order to answer this question, each unique visited location is counted. For each trip the postcode of the origin and destination is available (table 1). For trips either beginning or ending in the Netherlands, this postcode is used to identify the unique locations that are visited. The postcode used in the Netherland consists of 4 numbers and two letter (e.g. 1234 AB). The first two number in the code system represent a region in the Netherlands (Figure 16). The second two numbers represent a district in a city. The two letters often represent a specific (part of a) street. The system that registers the origins and destination of the lease car trips (using GPS) has a certain margin of error. Therefore, the same destination can sometimes be registered under different postcodes. In order to account for this, the unique locations are determined on the district level (the first four numbers) instead of on a street level (four numbers and two letters). For international locations, the whole postcode is used[10].

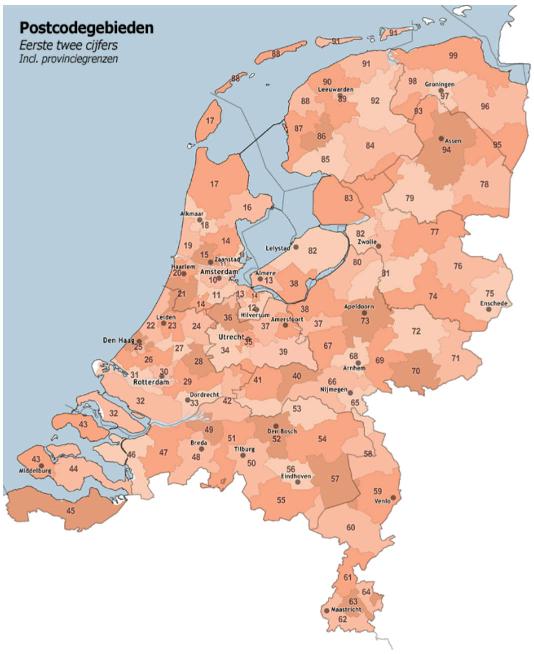

FIGURE 16 REGIONS CORRESPONDING TO THE FIRST 2 NUMBERS OF THE DUTCH POSTCODE SYSTEM (AALST, 2010)

The number of unique visited locations are also calculated on a per car basis. The distribution of the number of unique locations for the whole dataset will give insight whether a small percentage of the total cars is responsible for a large number of unique visited locations, or if the number of unique locations visited per car are more evenly spread over the whole lease car fleet.

The number of trips to locations outside of the Netherlands are presented to quantify the international usage of the lease cars.

[10] For international locations, the postcode system is different. Therefore, the location on a district level cannot be obtained by removing the letters. However, this is less of a problem because the international locations are visited much less frequent, automatically resulting in less wrong duplicates of unique locations, see also table 4.

The movement of the entire lease car fleet during the months for which data is available, is visualised (by creating an animation). In order to determine the locations of the lease cars, the latitude and longitude coordinates of the origin and destination of all trips are added to the dataset. This is achieved by connecting the trip database to a table containing the latitude and longitude coordinates of all the postcodes in the Netherlands (Postcodedata.nl, 2014). For international locations, the geographical coordinates of the visited city are used (Geonames.org, 2015). The location data is then used to plot the location of each lease car on the world map at 2 minute intervals (in time) from the start of the trip database (1st of January 2015) until the end of the database (31st of August 2015). It is not feasible to calculate the route that the car has followed to travel from its origin to its destination because of time restrains[11]. Therefore, the animation shows the cars travelling as the crow flies. The animation is used to identify general transport patterns during the day. When a car has reached its destination, its parking location is also shown on the map. The animation thus shows when cars are on the road and, after reaching their destinations, where they are parked (for each 2 minutes contained in the trip database). In order to keep the animation understandable, the parking location of the lease cars are aggregated. All cars parked in a radius of 20 km are allocated to the same (closest) parking spot. The resulting parking locations correspond to the large cities in The Netherlands (and Europe).

Because of the limited capabilities of paper to visualize animations, time independent maps of the parking locations and travel patterns of the lease car fleet are generated to present in this thesis. These time independent maps represent the parking and travel patterns of the entire lease fleet during the period for which data is available.

Lastly, the car movement to and from the different Capgemini offices in the Netherlands are discussed. The used dataset does not actually contain information about whether a lease car is used to visit a Capgemini office. The geographical (latitude/longitude) location of the Capgemini offices are publically available. It is assumed that all cars parked within a radius of 1 kilometre of a Capgemini office are lease cars that were driven to visit the respective office. This will result in some estimation error because a lease car could be parked near a Capgmini office, whereas the employee has an appointment at a different company located very close the Capgemini office. Vice versa, an employee could park his car further then 1 kilometre from the Capgemini office while actually visiting a Capgemini office. However, in general it is expected that the above described method will reasonably accurately estimate whether a lease car is used to visit a Capgemini office or not because all Capgemini offices have large parking lots located within a 1 kilometre radius.

4.3 Geographical data analyses results

Unique locations

The table below shows the number of unique location visited by the lease car fleet.

Usage statistic	Value	Description
Number of unique origins	3,818	Number of unique locations from which cars started their journey
Number of unique destinations	3,842	Number of unique locations to which cars drove
Number of unique Dutch origins	2,899	Number of unique locations in the Netherlands from which cars started their journey
Number of unique Dutch destinations	2,912	Number of unique locations in the Netherlands to which cars drove
Number of unique international origins	919	Number of unique locations outside of the Netherlands from which cars started their journey
Number of unique international destinations	930	Number of unique locations outside of the Netherlands to which cars drove

TABLE 4 NUMBER OF UNIQUE ORIGINS AND DESTINATIONS VISITED BY THE LEASE CARS, AGGREGATED BY ONLY USING THE FIRST FOUR NUMBERS OF THE DUTCH POSTCODE SYSTEM. INTERNATIONAL POSTCODES ARE NOT AGGREGATED.

[11] The exact route the car took to arrive at its destination is not saved, only its origin and destination. A best guess about the route taken by car can be calculated using routing software. However, routing half a million trips (table 2) takes a lot of time. Moreover, the resulting routes do not represent the actual travels, but only the most likely route. Therefore, no routing was calculated.

The postcode system in the Netherlands ranges from 1000 up until 9999. Theoretically, this gives a total of 8,999 possible postcodes that could be visited by car. However, not all postcodes are in use. Out of the total 8,999 combinations, 4,766 have a physical location (Postcodedata.nl, 2014). This means that out of all the city districts in the Netherlands, roughly 61%[12] had a Capgemini lease car either travelling to it, from it, or both. Thus, the lease cars are travelling to a great variety of locations in the Netherlands. It is however still possible that the lease cars mainly travel in certain regions of the Netherlands. For example, the 61% visited city districts could all be located in the west of the Netherlands.

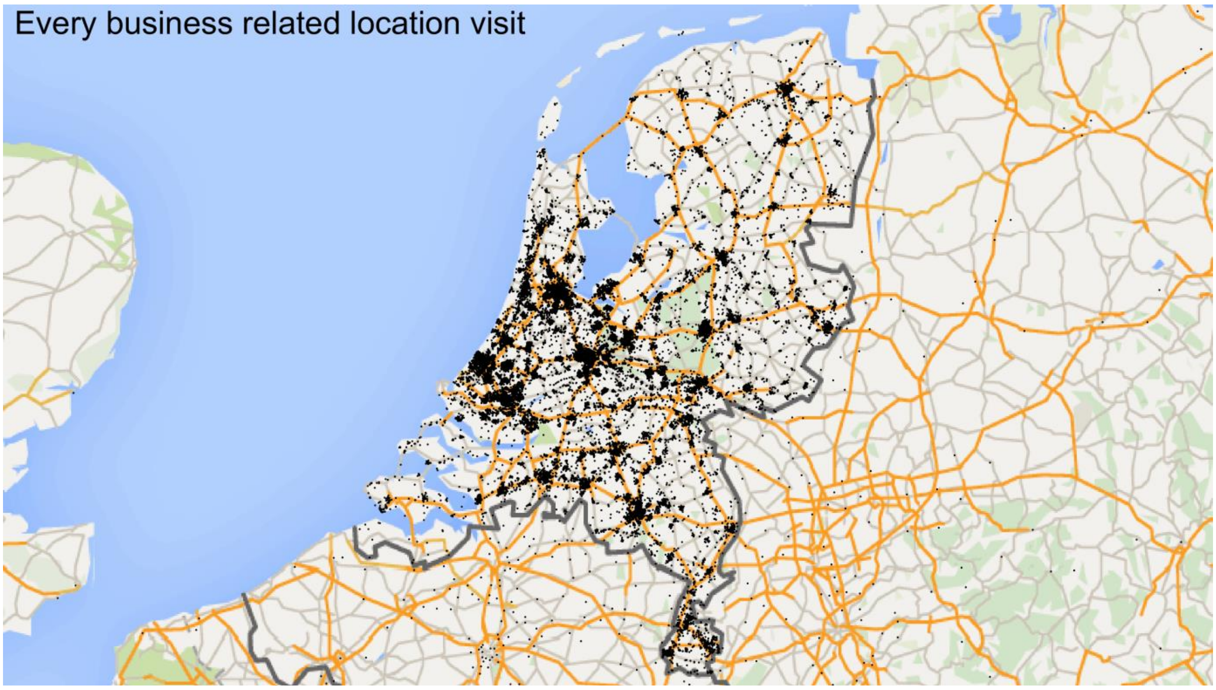

FIGURE 17 EVERY LOCATION IN OR NEAR THE NETHERLANDS VISITED BY A CAPGEMINI LEASE CAR FOR BUSINESS PURPOSES (TIME INDEPENDENT).

Figure 17 shows every location in the Netherlands (and abroad) that was visited by a Capgemini lease car during the data period. Figure 17 thus contains both the work and home locations. Clusters of location visits can be seen around the large cities. An increased intensity in location visits is observed in the west of the Netherlands. Also note a number of stops on the high way. These stops might be related to cars buying gas. Figure 17 shows the distribution of visited location in the Netherlands, but it does not clarify how many of these locations are visited by single lease car in the fleet. Therefore, the number of unique visits per car will be analysed next.

12 $\frac{2,899}{4,766} * 100 \approx \frac{2,912}{4,766} * 100 \approx 61\%$

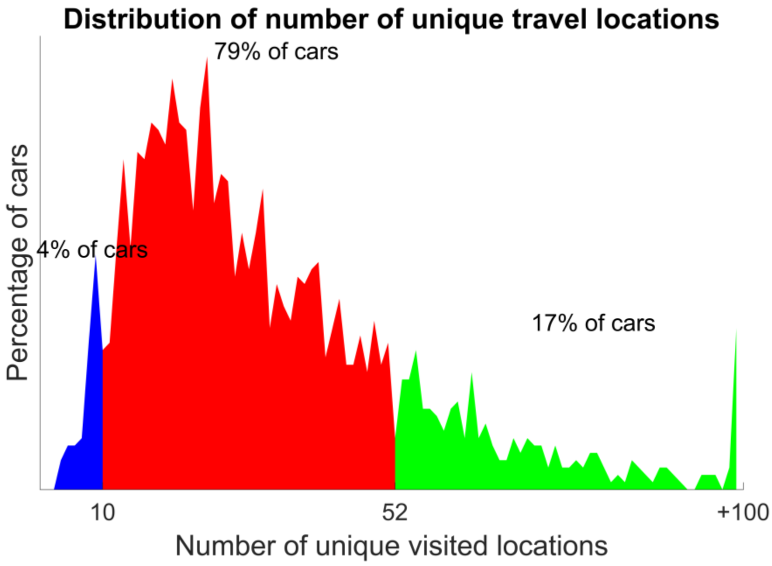

FIGURE 18 DISTRIBUTION OF THE NUMBER OF UNIQUE TRAVEL LOCATIONS VISITED BY THE ENTIRE LEASE FLEET. DUTCH UNIQUE TRAVEL LOCATIONS BASED ON CITY DISTRICTS.

Figure 18 shows the percentage of the car fleet that visits a certain number of unique locations. A number of things are noticed. Only 4% of the entire car fleet visits 10 unique locations or less. This indicates that most lease car users actually use the lease car to travel to numerous different destinations (instead of a fixed to and fro, from their residence to their work and vice versa). The largest part of the lease fleet (79%) visited between 11 and 52 unique locations. The peak is located at roughly 30 visited location. Considering 34 work weeks are contained in the dataset, this means that roughly each week between 0.3 and 1.6 new locations are visited using a lease car by 79% of the lease car fleet. The remaining 17% of the lease car fleet visit 52 unique locations or more. Figure 18 indicates that the lease car users work at varying locations. Figure 18 does not clarify how often each unique location is visited. So it is still possible that an employee commutes from and to the same location for 7 months, and then in the 8th month start a courier service (hypothetically), visiting 100 new locations (once) in four weeks time. Figure 19 clarifies the relation between the number of unique locations, and number of visits to that location for the car fleet.

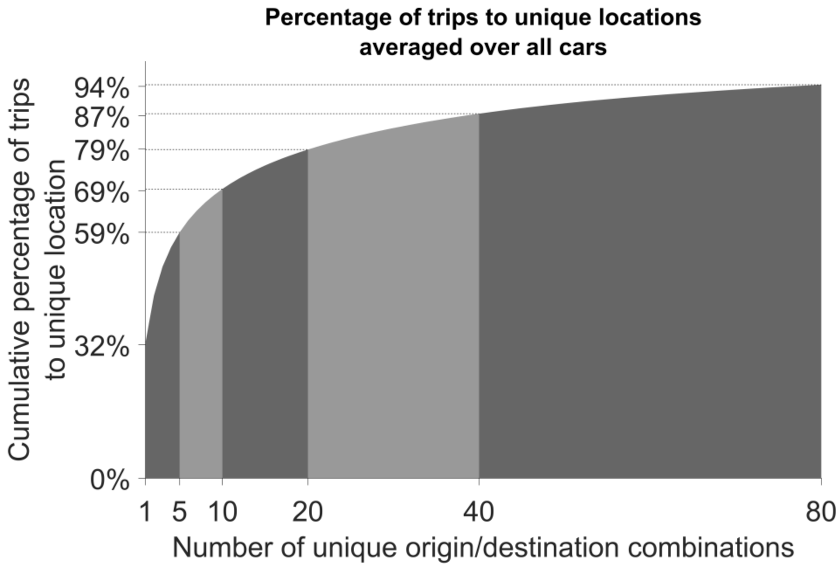

FIGURE 19 THE PERCENTAGE OF TOTAL TRIPS TO A CERTAIN NUMBER OF UNIQUE ORIGIN/DESTINATION COMBINATION. UNIQUE ORIGIN/DESTINATION COMBINATION DETERMINED PER CAR. CUMULATIVE TRIP PERCENTAGES BASED ON THE TOTAL NUMBER OF TRIPS IN THE DATABASE.

Before figure 19 is discussed, first a short explanation is given how figure 19 is created. This will clarify what figure 19 actually depicts. For each separate lease car, the number of trips to all of their unique origin/destination combination are counted. For each car, the number of trips are then sorted, resulting in a list per car with the most often visited origin/destination combination on the top, the second most visited origin/destination combination as the second list entry, etc. A new list is then generated for the entire lease fleet by adding all first entries, on the lists, adding all second entries, adding all third entries, etc. The cumulative sum of the entire lease fleet list is then calculated. The last entry on this list (at 100+ unique origin/destination combination, see figure 18) represents all trips that are performed during the 8 months of data. The list is visualised in figure 19. Figure 19 depicts how much percent of the trips were performed to/from the first unique origin/destination combination of the separate car lists, to/from the first and second origin/destination, etc. up until the first 80 list entries.

Figure 19 shows that 32% of the trips performed are to the same origin/destination combination. Thus, a large percentage of the trips are recurring travels to and from a single origin/destination combination. This probably is the result of employees working and living at fixed locations and commuting to and from these locations each day. Of all trips, 59% are directed to the first 5 origin/destination combinations of all cars. Addition of subsequent origin/destination combinations results in less and less additional percentage points. Figure 18 showed that 80% of the car fleet visited between 10 and 52 unique locations. However, figure 19 proved that although a large number of unique locations are visited, a relative small amount of origin/destination combinations are frequently visited. All other locations are only occasionally visited. It is expected that the big wins for changing travel needs satisfaction can be won by performing the recurring trips using alternative transport methods.

Figure 18 and 19 are generated without merging trips with 15 minutes in between them or less. This is was purposely done because regular visits to gas stations are necessary, and should be counted as a unique origin/destination combination as such. When merging trips with 15 minutes in between or less, the number of unique origins and destinations change somewhat.

Usage statistic	Value	Description
Number of unique origins	3,353	Number of unique locations from which cars started their journey
Number of unique destinations	3,434	Number of unique locations to which cars drove
Number of unique Dutch origins	2,835	Number of unique locations in the Netherlands from which cars started their journey
Number of unique Dutch destinations	2,885	Number of unique locations in the Netherlands to which cars drove
Number of unique international origins	518	Number of unique locations outside of the Netherlands from which cars started their journey
Number of unique international destinations	549	Number of unique locations outside of the Netherlands to which cars drove

TABLE 5 NUMBER OF UNIQUE ORIGINS AND DESTINATIONS VISITED BY THE LEASE CARS, AGGREGATE USING THE FIRST FOUR NUMBERS OF THE DUTCH POSTCODE SYSTEM. INTERNATIONAL POSTCODES ARE NOT AGGREGATED. TRIPS WITH 15 MINUTES IN BETWEEN OR LESS ARE MERGED.

Table 5 shows that especially the unique international origins and destinations are decreased when trips with 15 minutes in between them or less are merged. This is most likely related to the fact that during long international travels timely stops for gas or bathroom breaks are performed.

After merging, figure 19 also changes (see figure 20):

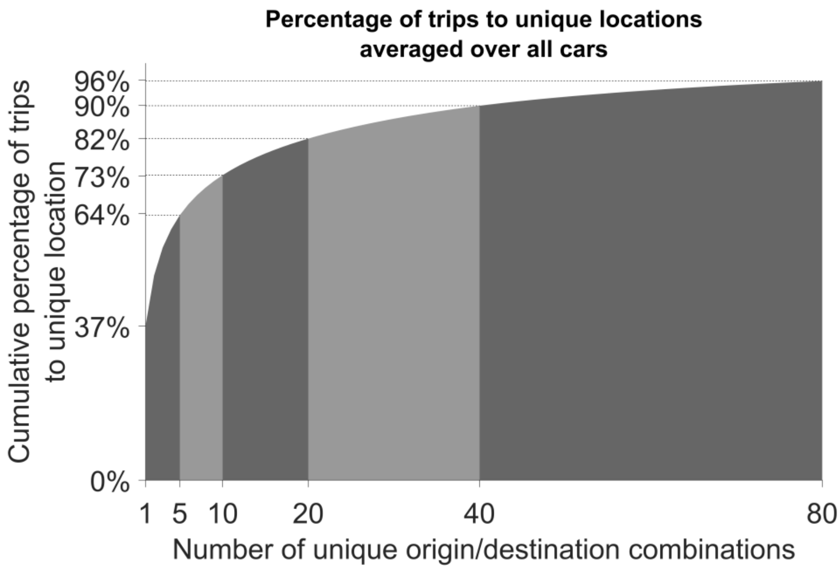

FIGURE 20 THE PERCENTAGE OF TOTAL TRIPS TO A CERTAIN NUMBER OF UNIQUE ORIGIN/DESTINATION COMBINATION. UNIQUE ORIGIN/DESTINATION COMBINATION DETERMINED PER CAR. CUMULATIVE TRIP PERCENTAGES BASED ON THE TOTAL NUMBER OF TRIPS IN THE DATABASE. TRIPS WITH 15 MINUTES IN BETWEEN OR LESS ARE MERGED.

Comparing figure 19 and 20 reveals that after merging the trips, a small increase in the percentage of the trips to the same origin/destination combination is obtained. Figure 19 and 20 roughly show the same pattern of only a small number of unique origin/destination combinations being frequently visited.

The following is concluded:

- Roughly 61% of the four digit postcode locations in the Netherlands had a Capgemini lease car either travelling to it, from it, or both. Thus the Capgemini lease cars are driven to a great variety of locations.
- Most lease car users actually use the lease car to travel to numerous different destinations. Only 4% of the entire car fleet visit 10 unique locations or less. 79% of the lease fleet visited between 11 and 52 unique locations.
- Each week, roughly between 0.3 and 1.6 new locations are visited using a lease car by 79% of the lease car fleet.
- Although a large number of unique locations are visited, a relative small amount of origin/destination combinations are frequently visited. This patterns is strengthened after merging trips with 15 minutes in between.

INTERNATIONAL TRAVELS

Country	Trips origin	Percentage of total	Trip destinations	Percentage of total
Austria	103	0.02%	107	0.02%
Belgium	3,357	0.64%	3,380	0.65%
Switzerland	118	0.02%	122	0.02%
Czech Republic	10	0.00%	11	0.00%
Germany	5,236	1.00%	5,271	1.01%
Denmark	4	0.00%	4	0.00%
Spain	56	0.01%	56	0.01%
France	528	0.10%	534	0.10%
United Kingdom	30	0.01%	29	0.01%
Greece	1	0.00%	1	0.00%
Hungary	1	0.00%	1	0.00%
Italy	71	0.01%	69	0.01%
Luxembourg	23	0.00%	22	0.00%
Netherlands	514,012	98.17%	513,944	98.15%
Norway	58	0.01%	57	0.01%
Poland	3	0.00%	3	0.00%
Sweden	1	0.00%	1	0.00%

TABLE 6 TRIP COUNTRY OF ORIGIN AND DESTINATIONS

Table 6 shows the 17 countries that had a car originating from or arriving to it. Unsurprisingly, the Netherlands has the most trips originating from and/or arriving in it. In fact, only 2% of all trips did not start or finish in the Netherlands. Note that some countries are visited by car, which take a long time to reach by car (Greece, lower parts of Italy). It is unclear why it is chosen to partake these trips by car instead of airplane.

The travel improvement analyses in the coming chapter will primarily focus on improving domestic (the Netherlands) travels. Because only 2% of the trips are international, it is expected that the biggest wins for travel improvements will be found by improving domestic travels.

Based on the distribution of national and international trips, the following is concluded:

- The Capgemini lease car fleet is primarily used in the Netherlands.
- Because only 2% of the trips are international, travel improvements will be primarily explored domestically.

CONGLOMERATION OF CARS OVER THE NETHERLANDS

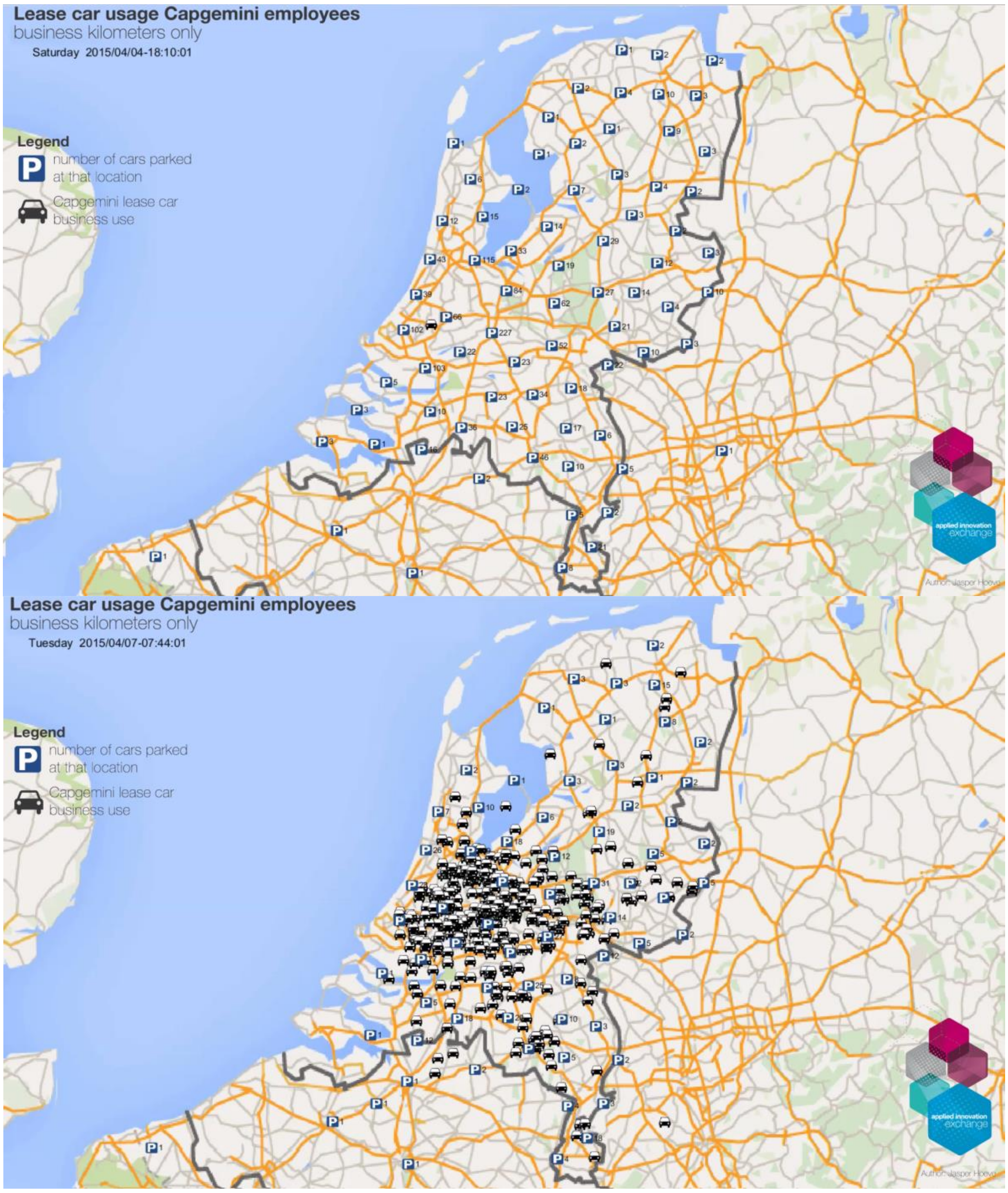

FIGURE 21 SNAPSHOTS OF THE LEASE CAR ANIMATION. VISUAL OVERLAY DESIGN BY ANIKA SIEPEL.

Figure 21 shows two snapshots of the animation made to analyse the travel patterns of the lease car fleet. Each second in the animation represent 1 hour of real time movements. The total period for which data is available equals 242 days (table 2), thus the animation has a total length of roughly 1.5 hours[13]. The animation is analysed at numerous (+10) occasions for periods of roughly 10 minutes (unstructured observations). A number of things are noticed when watching the animation. The cars moving during the animation appear to originate from all over the Netherlands. Each province has both cars coming from and going to it at some point in the animation. Outside of business hours, each province has multiple areas where one or multiple (hundreds of) cars are parked. Most car movements are centred around Amsterdam and Utrecht. Increased car movement is expected there considering that two offices of Capgemini are located in Utrecht and Amsterdam (table 7). During the whole animation, only little periods are observed with no car movements whatsoever. Little car movement is usually seen between 2.00 and 4.30 at night. During weekends car movements is also reduced (but cars still move during daytime and at night). A lot of cars are on the road during rush hour (which was already discussed in chapter 3). In fact, so many cars are moving during rush hour that it's hard to see where the cars are coming from and where they are going to. Therefore, time independent maps of the parking locations and car movements are produced using the generated animation.

Time independent maps of the parking location hot spots and the work day averaged car movements are generated. The car 'park' hotspots and car movements during the day are calculated by measuring the car locations at 3.00 and 11.00 each work day. These measurement moments were chosen because outside of work hours and during work hours, at 3.00 and 11.00 respectively, the least number of cars are moving (figure 14).

Figure 22 depicts the number of cars that are 'parked' during and outside of business hours averaged over the entire period (work days) for which data is available. Both during and outside of business hours, cars are primarily 'parked' in the Utrecht and Amsterdam region. On average 462 and 224 cars are 'parked' near Utrecht during and outside of business hours respectively. For Amsterdam, 224 and 128 cars are 'parked' during and outside of business hours respectively (Appendix G). Both during and outside of business hours, these two cities contain the largest number of cars. However, roughly half of the cars move to a different location outside of business hours. The Hague and Rotterdam are in the hotspot top four with roughly 100 cars 'parked' near them, regardless of the time of day. The Hague and Rotterdam differ from Utrecht and Amsterdam in that they apparently have an equal number of employees working and living there.

Looking at the more country wide patterns in figure 22, a number of things are observed. A conglomeration of cars occurs during business hours. Roughly 900 cars or 51% of the entire car fleet is on average 'parked' in the top 4 regions (Utrecht, Amsterdam, The Hague, Rotterdam). Outside of business hours the top 4 regions only account for 590 or 34% of the entire car fleet. Visual analysis of figure 22 reveals that outside of business hours a larger amount of regions contain tens of cars compared to during business hours. Outside of business hours a decentralisation of cars occur. This can be explained using figure 23.

[13] $242\ days \times 24 \frac{hours}{day} \times \frac{1}{3{,}600} \frac{second}{hour} = 1.49\ hours$

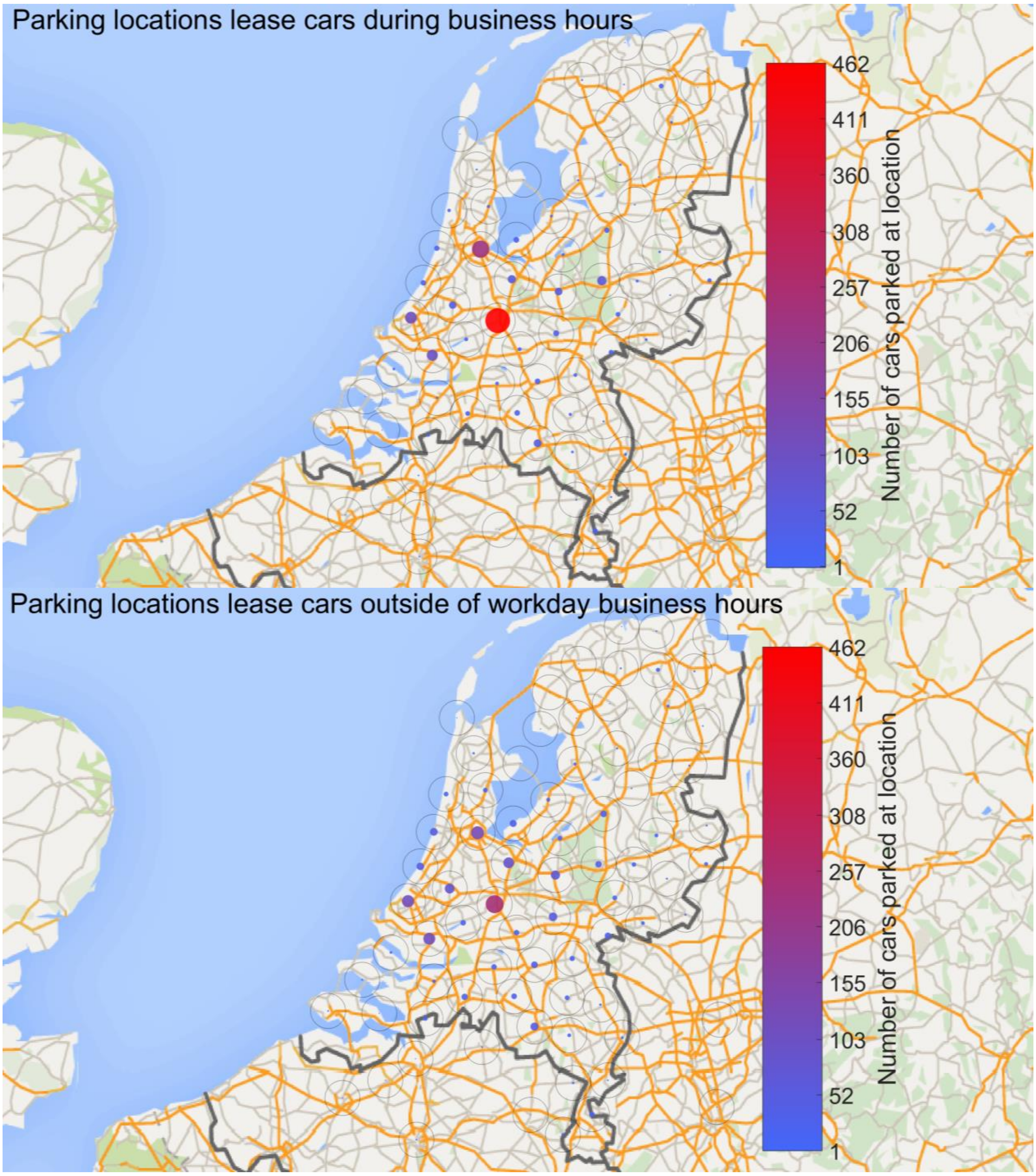

FIGURE 22 MAPS (WORKDAY AVERAGED) DEPICTING THE PARKING HOTSPOTS DURING BUSINESS HOURS AND OUTSIDE OF BUSINESS HOURS. THE LARGER TRANSPARENT CIRCLES APPROXIMATE (SEE APPENDIX F) THE 20 KM RADII WITHIN WHICH ALL 'PARKED' CARS ARE SUMMED UP.

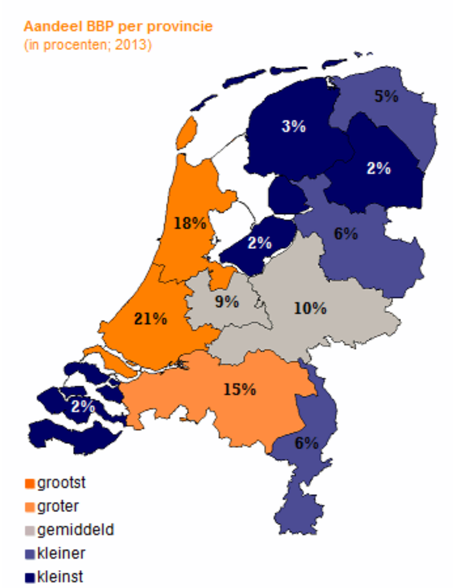

FIGURE 23 PERCENTAGE OF GROSS DOMESTIC PRODUCT EARNED IN EACH REGION IN THE NETHERLANDS (ING, 2013)

Figure 23 shows that the most gross domestic product in the Netherlands is earned in the western and southern provinces. Capgemini provides consultants in the ICT business (who often work at the office of the customer). Customers of Capgemini are often large organization. Therefore, Capgemini employees often reside in the top 3 gross domestic product provinces (either at the customers office or at a Capgemini office). However, in the same top 3 gross domestic product provinces, the cost of renting/buying a house is the highest of the Netherlands (NVM, 2015). Therefore, it can be expected that a number of employees chose to rent/buy residence somewhere outside of the top 3 provinces. This results in a conglomeration of lease car during the business hours, but a de-centralization of lease cars outside of business hours.

Figure 22, does not show the movements of cars, only the number of cars ‘parked’ at a number of locations. It is possible that the 224 cars ‘parked’ outside of business hours in Utrecht are not contained in the 462 cars that are ‘parked’ in Utrecht during business hours. Therefore, the fluxes of cars in between parking locations during morning and evening rush hour are visualised.

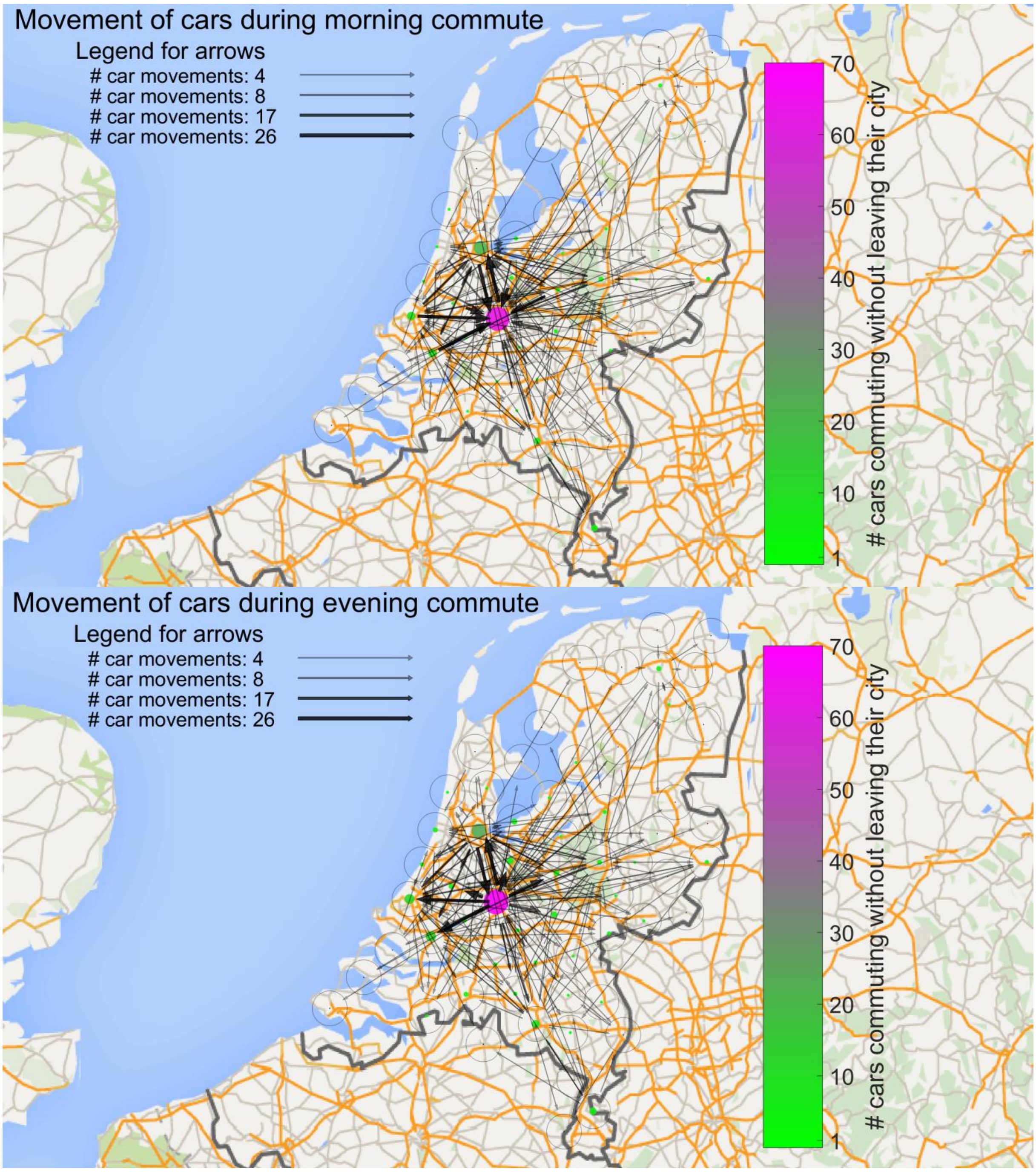

FIGURE 24 (WORKDAY AVERAGED) LEASE CAR FLUXES IN BETWEEN PARKING LOCATIONS DURING MORNING AND EVENING RUSH HOUR.

Figure 24 shows the number of cars travelling from one parking location to another during the morning and evening rush hour. It is shown that during the morning rush hour, a lot of cars 'parked' at small cities and villages travel to either Utrecht, Amsterdam, The Hague, or Rotterdam. This confirms the pattern of conglomeration of cars during business hours. Vice versa, during the evening rush hour, a lot of cars are travelling from the large cities back to the decentralised parking locations. Beside the top 4 parking locations, Apeldoorn and Eindhoven are also identified as locations to which cars congregate during morning rush hour. Conglomeration to Apeldoorn and Eindhoven is not unexpected because Capgamini also has offices there (table 7).

Between Amsterdam and Utrecht an exchange of cars is taking place each day, where people living in Amsterdam work in Utrecht and vice versa. Furthermore, a number of cars travel from the Hague and Rotterdam to Utrecht and Amsterdam during the morning commute. At the same time, a number of decentralised cars travel from their location to The Hague and Rotterdam. This results in roughly the same cars ‘parked’ at The Hague and Rotterdam during and outside of work hours.

The above discussed travel patterns are all related to travel between cities. Figure 24 also shows that a number of cars (especially in the top 2 parking locations; Utrecht ± 65, Amsterdam ± 25) on average do not leave their city when they travel during morning or evening rush hour. This seems to indicate that a number of cars only travel a short distance each day (also discussed in chapter 3).

The following is concluded based on the analyses of the distribution of cars over the Netherlands:

- Each province has both cars coming from and going to it during the 8 months for which data is available.
- Most car movements are centred around Amsterdam and Utrecht where the Capgemini offices are located.
- Roughly 50% less cars are ‘parked’ in Utrecht and Amsterdam outside of business hours, compared to during business hours.
- Only little periods are observed with no car movements whatsoever.
- During and outside of business hours, cars are primarily ‘parked’ in the Utrecht, Amsterdam, The Hague and Rotterdam regions.
- A conglomeration of cars occurs during business hours around the above mentioned regions, decentralization of cars occurs outside of business hours.
- Between Amsterdam and Utrecht an exchange of cars is taking place each day.
- A number of recurring car travels never leave the city they start in.

Car movement to Capgemini offices

Commutes specifically to Capgemini offices are analysed further. Capgemini has offices at 8 different locations in the Netherlands.

City	Location
Utrecht	Leidsche Rijn (headquarters)
Utrecht	Papendorp
Amsterdam	Archangelkade
Amsterdam	Zuid Oost
Apeldoorn	Fauststraat
Eindhoven	High Tech Campus
Groningen	Rozenburglaan
Heerlen	Vogt

TABLE 7 DUTCH CAPGEMINI OFFICES

The Amsterdam Archangelkade location is a data centre of Capgemini. Thus ‘regular’ employees (consultants) hardly visit this location. The Heerlen office is a only a very small office (two rooms). Thus this location is also hardly visited.

Figure 25 shows the average number of cars ‘parked’ at the 8 Dutch Capgemini offices. The Utrecht Leidsche Rijn office is by far the office with the most cars. All other offices only have a few cars ‘parked’ at them on average during business hours. Outside of business hours, all but a few cars leave the Capgemini offices. This is expected because employees tend to take their lease car back home. Comparing figure 25 to figure 22 shows that half of the cars ‘parked’ in Utrecht during business hours are ‘parked’ at the Capgemini offices. For Amsterdam, less than 20% of the cars ‘parked’ are actually ‘parked’ at the Capgemini offices there. Out of all performed trips, 8.35% were trips to a Capgemini office, where an employee stayed at this office for four hours or more before leaving again. The relative small number of trips to Capgemini offices indicate that most Capgemini employees work at clients instead of at Capgemini offices.

The following is concluded:

- During office hours, the Capgemini office at Leidsche Rijn has the most lease cars parked.
- All other Capgemini offices only have a few cars ‘parked’ during business hours.

- Outside of business hours, Capgemini offices have almost no ‘parked’ cars.
- On average 15%[14] of the entire Capgemini lease fleet is ‘parked’ at a Capgemini office during office hours.
- Although 900 cars are ‘parked’ in the top 4 most ‘parked’ regions, only 222 cars out of these 900 are ‘parked’ at a Capgemini office. Thus the top 4 regions have a lot of Capgemini employees visiting them primarily because of the large concentration of companies there (figure 23), not because the Capgemini offices are located there.

FIGURE 25 WORKDAY AVERAGED NUMBER OF CARS ‘PARKED’ AT THE CAPGEMINI OFFICES DURING AND OUTSIDE OF BUSINESS HOURS.

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[14] On average, there are a total of 262 cars parked at a Capgemini office during business hours. This corresponds to $\frac{262}{1729} \times 100 \approx 15\%$ of the total lease car fleet.

4.4 Evaluation of travel patterns

Based on the analyses of chapter 3 and 4, a general impression about the lease car usage is given. Trips are overwhelmingly performed within the Netherlands (table 6). Although a large number of unique locations are visited (table 4), a relative small amount of origin/destination combinations are frequently visited (figure 19). A conglomeration of cars occurs during business hours, decentralization of cars occurs outside of business hours (figure 22). The Capgemini lease cars are primarily used for commuting (figure 14), mostly to the Utrecht and Amsterdam regions, from numerous decentralised location in the Netherlands (figure 24). These regions are primarily visited because of the large concentration of companies there (figure 23). The fact that Capgemini offices are located in Utrecht and Amsterdam only contributes to the number of cars 'parked' there to a lesser degree (figure 25). Other locations that are frequently visited during business hours are Rotterdam, The Hague, Apeldoorn and Eindhoven (figure 24). Especially in Utrecht and Amsterdam, a number of recurring car travels never leave the city they start in (figure 24). The lease cars in the fleet are not driven every work day and are also used (to a lesser degree) for business trips beside commuting (figure 9).

In the following chapter, travel improvements are explored taking the present travel pattern into account.

5. Potential travel improvements

5.1 Introduction

This chapter describes the opportunities, and expected benefits of improving the Capgemini lease car usage. The analyses focus on expected big wins. A number of changes are considered: Carpooling, using the train instead of the car, travelling by bicycle instead of by car, encouraging employees to work at the nearest Capgemini office and using the shared lease car pool more efficiently. These changes in the way employee travel needs are satisfied were chosen in collaboration with the Director Facilities at Capgemini, Jack Knol. It is expected that these changes will result in significant financial or environmental benefits. Estimated financial and environmental benefits of the changes in the way employee travel needs are satisfied are therefore discussed. The expected tradeoffs of the changes in the way employee travel needs are satisfied are also discussed.

5.2 Changing car fleet usage: scope and approach

Introduction

This section discusses the methods used to find a number of trips that can be improved and to quantify the benefits of changing the way employee travel needs are satisfied. Five opportunities for travel need satisfaction are proposed. Each travel need satisfaction opportunity is reviewed in isolation (thus without considering the effects of the other opportunities). This was done to better compare the effects of all different opportunities for travel need satisfaction. First a number of boundary conditions are proposed. These boundary conditions represent (changes in) quantities of time and distance, for a number of transport modes, that are deemed acceptable in order to still comfortably travel for business purposes.

Scope

The scope of this study (chapter 1) specifically does not focus on the willingness of employees to change their travel behaviour. However, the effectiveness of changing car fleet usage depends on the willingness of employees to take detours of a certain length, or travel using different transport modes. Therefore, a number of boundaries for detour length/duration and maximum walking and cycling distances are set. These boundaries are primarily set based on reasonable distances and durations that people travel using the specific transport modes. The boundaries are also designed based on the assumption that an incentive system is set in place by Capgemini to encourage employees to adjust their travel behaviour.

Car

In order to more efficiently satisfy the transport need of all lease car using employees, it is assumed that individual lease car users can be persuaded to take a detour from their quickest route to their destination. A detour of 5 kilometres measured from the trip origin or trip destination is deemed the maximum allowable detour that can be expected from a lease car user. The maximum allowable detour is set based on a maximum travel time delay of 36 minutes, as described below.

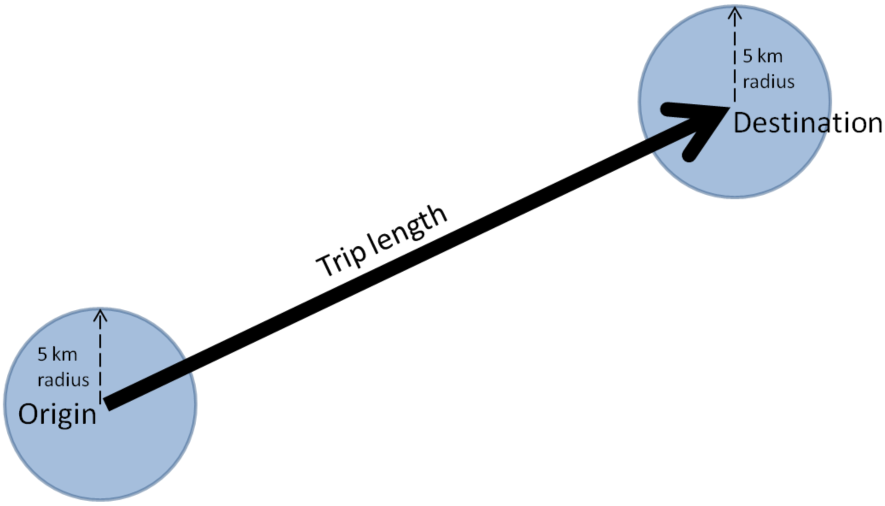

FIGURE 26 EXAMPLE OF DETOUR KILOMETRES POSSIBLY MADE BY CAPGEMINI LEASE CAR USERS IN ORDER TO FACILITATE TOTAL EMPLOYEE TRAVEL NEED.

In the worst case scenario, the detour results in the lease car user is travelling 20 kilometres more than he would have when not taking a detour. Assuming this detour is taking place during rush hour in the Netherlands, then the worst possible average travel speed equals 34 km/hour[15] (N213 near The Hague, INRIX, 2014). Thus the worst possible detour imaginable (20 km's), at the worst possible time, at the worst possible location, would result in a trip delay of $\frac{20\ km}{34\ km/h} \times 60\ {}^{min}/_{h} \approx 36\ min$. This worst case scenario is the limit of the average time delay an employee can expect to incur when taking a detour. However, this being a worst case scenario, most detours will take a shorter amount of time then the above mentioned extreme.

Beside an increase in travel time, it is also assumed that employees are willing to adjust their time of arrival at their destination in order to more efficiently satisfy the transport needs of the entire lease car using population. It is assumed that employees are willing to arrive up to 15 minutes earlier or 15 minutes later at their destination in order to facilitate someone else's travel need[16]. Changing the preferred time of arrival does not necessarily result in a travel time delay because these 15 minutes can be used productively in one way or another.

Bicycle

According to a survey of the Central Statistical Office (CBS) Dutch commuters prefer using the bicycle when commuting distances up to 12.5 kilometres (single journey) (CBS, 2001). It is assumed that Capgemini employees are willing to travel up to 12.5 kilometres single journey using a bicycle.

Every trip shorter than 12.5 kilometres is classified as performable by bicycle. However, when numerous business trips are performed during the day (all shorter than 12.5 kilometres), this could result in a situation where an employee has to travel hundreds of kilometres per day using the bicycle. In order to prevent this, a limit of 36 bicycle kilometres per day is set. The average bicycle velocity is 18 kilometres per hour (fietsersbond.nl, 2013), thus this limit results in a maximum bicycle time of 2 hours per day.

No differentiation is made between usage of a normal bicycle and an E-bike in this study. Further research taking into account the distances people are willing to travel by E-bike is recommended.

Walk

The average walking speed of pedestrians (ages 14 to 64) is 4.5 kilometre per hour (Knoblauch, Pietrucha, & Nitzburg, 1996). It is assumed that employees can be persuaded to walk distances up to 1.5 kilometres (single journey). This results in a maximum walking time of 20 minutes per walking instance.

[15] Of course worse travel times are possible when extreme weather or accidents cause additional delays. The stated average speed is based on regular traffic conditions.

[16] For future research, it is recommended to measure the actual willingness of Capgemini employees to wait for a carpool using, for example, a survey.

APPROACH: CARPOOLING

Why consider this change in satisfying transport need?

The first of five opportunities for changing the way travel needs are satisfied that are considered, is promoting employees to carpool when possible. Employees travelling from roughly the same location to a new location at roughly the same time can possibly share a car, instead of travelling to the new location with two (or more) cars. For each carpool, one lease car is driven less which is beneficial from a cost and environmental perspective.

How are the trips identified that could potentially be performed differently?

In order to find possible carpool opportunities, each registered trip in the dataset is compared to every other trip in the dataset. When two trips depart within a radius of 5 kilometres of each other, arrive at destination within a radius of 5 kilometres of each other, and arrive at the destinations within 15 minutes of one another (as defined in the scope discussed above), the two trips are classified as carpoolable. Additionally, the origin and destination of both trips should be located in the Netherlands. International trips are excluded because the exact locations (origin and destination) of those trips are less accurate then the trips located in the Netherlands (chapter 4). Because very little trips were performed outside of the Netherlands, excluding international trips is expected to have little effect on the total number of potential carpool trips. Trips that do not leave their aggregated city (see appendix F for definition of aggregated cities) are also excluded from possible car sharing. This was done to prevent unrealistic care sharing[17]. In order to quantify the effects of car sharing, it is assumed that one car can transport a maximum of two persons[18]. The car that drove the smallest distance from origin to destination is then removed from the total travelled kilometres (figure 27). Only trips performed during work days are taken into account. This was done in order to more accurately represent the carpool opportunities when aggregated to averages per (work) day[19]. Excluding weekend trips is expected to affect the total number of possible carpools very little due to the limited business trips performed during weekends (chapter 3). Performing the described carpool analysis will result in a rough estimate of the carpool opportunities for the Capgemini lease car users.

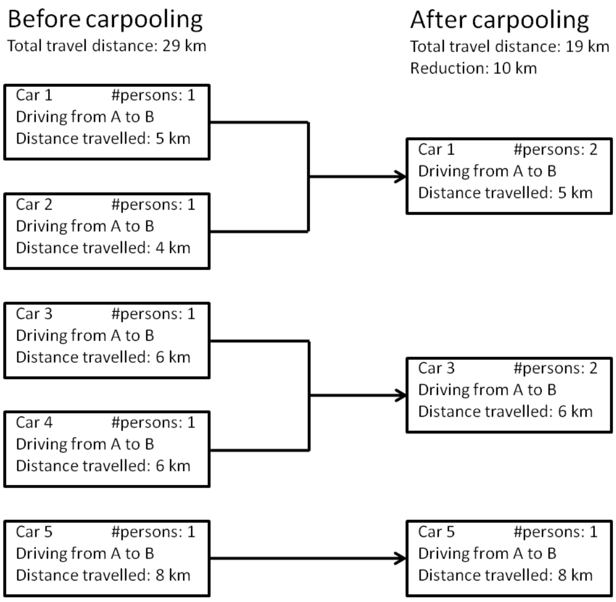

FIGURE 27 EXAMPLE OF CALCULATION FOR FINDING POSSIBLE CARPOOL OPPORTUNITIES AND THE RESULTING REDUCTION IN CAR KILOMETERS.

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[17] An example of unrealistic car sharing: An employee travels 4 kilometres by car from north to south Utrecht. Because of the small distance travelled, his destination is located in the 5 kilometre radius of his origin. Similarly, another employee is travelling 4 kilometres from south to north Utrecht. When trips in the same city are not excluded, these two employees would be counted as a possible car share opportunity, whereas they are actually travelling in opposite directions.

[18] Thus when three trips are found that are travelling from roughly the same origin, to roughly the same destination, at roughly the same time, the number of trips needed to transport these employees is only reduced by one. When four trips are found (ceteris paribus), then the number of needed trips are reduced by two.

[19] When the carpool opportunities are aggregated for all days of the week including the weekends, significantly lower carpools per day are found because of the reduced business trips during weekends (chapter 3).

The above described method for finding potential carpools might not give an accurate image of the actual carpools that would occur after encouragement from Capgemini management (financially, and/or by other means). It is hypothesised that a certain level of predictability is required in order for employees to logistically arrange a carpool at the location and time of their preference. To account for this, the potential carpools are filtered. It is assumed a carpool is only logistically possible when the specific carpool from A to B occurs either on a weekly basis three times in a row, or three times within 6 working days, with a maximum of 1 day in between (excluding weekends; figure 28).

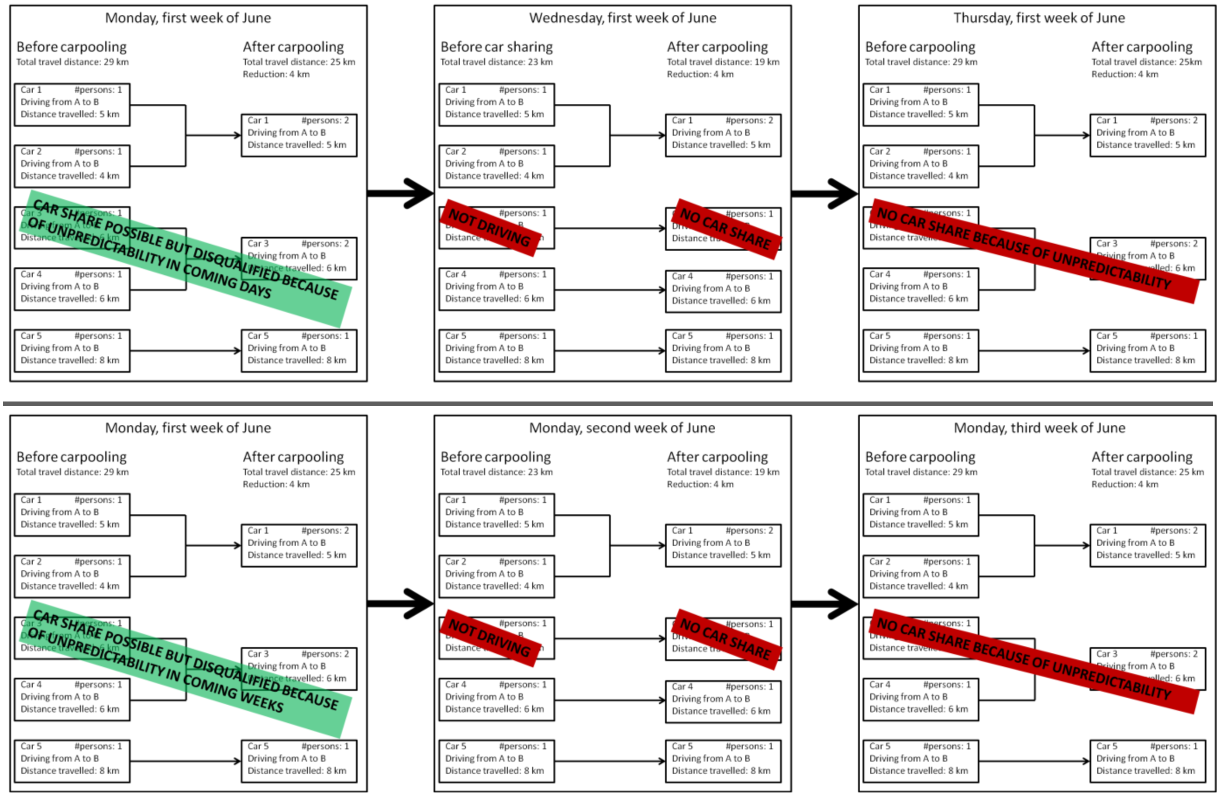

FIGURE 28 EXAMPLE OF POSSIBLE CARPOOL ACCEPTED (CAR 1 & 2) AND REJECTED (CAR 3 & 4) BECAUSE OF PREDICTABILITY AND UNPREDICTABILITY RESPECTIVELY.

Moreover, finding a carpool from A (home) to B (work) does not guarantee a carpool possibility from B (work) to A (home) at the end of the day. Because employees tend to prefer to get back home at the end of the day, a transport possibility back home is most likely a prerequisite for an employee to consider a carpool. Moreover, when an employee has to travel for business beside commuting, sharing a car might result in employees not being able to travel to their next meeting. To take this into account, all travel needs of an employee during the day are taken into account. Carpools are only deemed feasible when all employees involved can satisfy all their travel needs during the day under consideration using a carpool. Furthermore, at the end of the day, the employee should be within 2 kilometres of its starting point at the beginning of that day. This is necessary because the employee should be able to use his own car the next day.

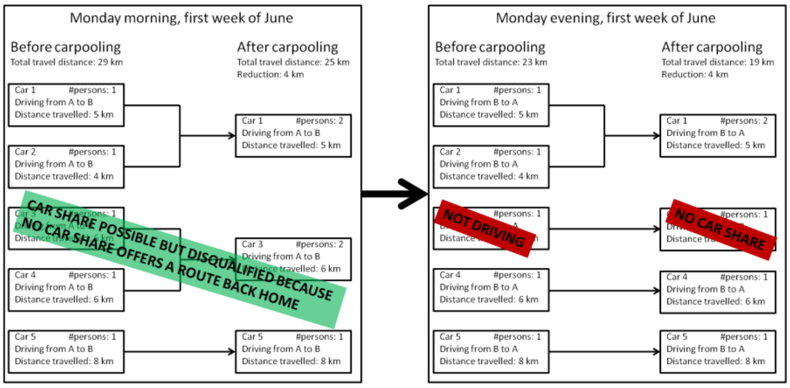

FIGURE 29 EXAMPLE OF POSSIBLE CARPOOLS ACCEPTED (CAR 1 & 2) AND REJECTED (CAR 3 & 4) BECAUSE OF THE ABILITY TO GET BACK HOME AT THE END OF THE DAY (CAR 1 & 2) OR NOT (CAR 3 & 4).

Three different scenarios for car sharing are thus under consideration:

Scenario name	Assumptions
Carpool rough	Assume an application exists that notifies Capgemini employees when another employee is leaving and from what location. This application can then be used to arrange a carpool ad hoc. When a car pool is found to travel from the home to the workplace but not vice versa, the employee uses public transport, to get back home.
Carpool recurring trips	No applications exists that notifies Capgemini employees about possible carpools. Therefore, carpool possibilities that are recurring and predictable are only feasible. When a carpool is arranged to travel from the home to the workplace but not vice versa, the employee uses public transport, to get back home.
Carpool getting home	An application exists that notifies Capgemini employees about a possible carpool. Alternatively, Capgemini employees rely on informal collaboration to arrange their carpools ad hoc. When a carpool is arranged to travel from the home to the workplace but not vice versa, the carpool is disqualified. Employees have little trust that public transport can get them back home.

TABLE 8 CARPOOL SCENARIOS

How are the benefits of this transport change quantified?

The effects of the different carpool scenarios are calculated using indicators for the cost reduction and carbon dioxide emission per kilometre driven. The Director Facilities of Capgemini, Jack Knol stated that each kilometre driven by a Capgemini car results in a 0.109 euro expenses for Capgemini[20]. This key figure is used in combination with the estimated reduction in kilometres driven (figure 27) to quantify the financial benefit for Capgemini of car sharing. The average carbon dioxide emission of the Capgemini lease car fleet is tracked by Capgemini. The average Capgemini lease car exhausts little over 140 grams of CO_2 per driven kilometre (Knol, 2015). It is assumed that every kilometre not driven by the lease car fleet therefore results in a carbon dioxide reduction of 140 grams.

Out of the roughly 3000 Capgemini lease cars, only 1729 are observed travelling during the 8 months for which trips data was available. Thus, only little more than half of the lease cars are analysed. Not all lease cars were found in the dataset because not all lease cars are outfitted with a trip tracking device yet. In order to correct the possible financial and environmental benefits for this, the expected benefits are extrapolated from 1729 to 3000 lease cars[21]. Moreover, because the dataset only contains all trips performed during 8 months, the expected bene-

[20] The savings for Capgemini, due to a reduction in the driven kilometres, consist of an increased residual value of the lease cars and a reduction in fuel costs. Note that the total costs of the lease car consist of the costs paid by Capgemini (roughly 0.109 euro per kilometre) and the costs of the lease contract subtracted from the employee mobility budget.

[21] Extrapolation done by multiplying the cost reduction and CO_2 emission reduction by $\frac{3000}{1729}$.

fits are also extrapolated to a full year[22]. This way, an estimation of the expected benefits over a whole year for the entire lease fleet is found. These extrapolations are also done for all other opportunities to change travel needs satisfaction discussed below.

APPROACH: TRAVEL BY TRAIN

Why consider this change in satisfying transport need?

More intensive use of the train for business travels is considered as a possible way to change the way travel needs are satisfied. It is hypothesised that using the train is cheaper and more environmentally friendly then using a lease car. Employees who live and work near a train station might be persuaded to travel by train instead of using their lease car.

How are the potential trips identified that are eligible for change in transport?

The geographical location of all train stations in the Netherlands as well as the distance (by rail) between each station combination is available publically[23] (rijdendetreinen.nl, 2016). This data is used to identify lease car trips that could have potentially been performed by train. The distance of the origin and destination of each trip in the lease car dataset is compared to the location of all train stations in the Netherlands. When both the origin and destination are located within a radius of 1.5 kilometre (walking distance) of a train station, the trip is deemed performable by train. Similar to the carpool potential, only trips performed during weekdays are considered. Because the accuracy of the trip origin and destination outside of the Netherlands are questionable, and only information about the Dutch train stations are available, only domestic business trips are considered when looking for trips potentially performable by train.

Similar to finding potential carpools, the potential train trips should also take into account that employees need to be able to reach every destination they want to travel to during a business day. The employees should also be able to return to their car at the end of the day. Therefore, the potential train trips are filtered similar to the potential carpool trips (figure 29).

Scenario name	Assumptions
Train rough	Employees make use of the train when possible. When a train ride is not possible, a car is available to them to satisfy their travel need.
Train getting home	When it is possible to travel from the home to the workplace by train but not vice versa, or when one of the non-commuting trips is not performable by train, all potential train trips during that day are disqualified.

TABLE 9 TRAIN SCENARIOS

How are the benefits of this transport change quantified?

Quantifications of the benefits of using the train instead of the car consists of two parts: the beneficial effects of using the lease cars less, and the disadvantageous effects of using the train instead. It was already discussed that every reduction in driven kilometre results in a 0.109 euro cost saving and 140g less CO_2 emission. The emission of carbon dioxide per driven kilometre per person in the train is dependent on the occupancy rate of that specific train. In the past, the Nederlandse Spoorwegen (NS) has stated several figures about the carbon dioxide emission per kilometre of their trains. However, due to some controversy of the calculation method, no official figures are given by the NS anymore (AMT, 2015; NS, 2016). When taking the average occupancy rate of the train into account, on average a train exhausts 50 grams of CO_2, according to the NS[24] (AMT, 2015). This key figure is used to estimate the exhausted CO_2 when a trip is performed by train instead of a lease car. The costs of a train ticket in the Netherlands is based on the distance travelled by train. The costs of the tickets per kilometre trav-

[22] Extrapolation done by multiplying the cost reduction and CO_2 emission reduction by $\frac{12}{8}$.

[23] Because the source of this data is somewhat unclear, the data was validated using Google Maps and the NS travel planner. Validation confirmed the accuracy of the data.

[24] When they still stated those numbers.

elled go down for each subsequent kilometre[25]. Because the exact distances between stations are known, the costs of the ticket when taking the train instead of the car can be calculated.

APPROACH: TRAVEL BY BICYCLE

Why consider this change in satisfying transport need?

Taking the bike instead of using the car is considered as the next opportunity for changing car fleet usage. The carbon dioxide emission of using a bicycle is negligible when lifecycle emission is ignored (CO_2 emission as the result of producing the bike) (Auchapt, 2013). Moreover, cycling has a net benefit for your health (De Hartog et al., 2010). Finally, by taking the bike, the cost of transportation is reduced by a significant amount, as will be discussed below.

How are the trips identified that could potentially be performed differently?

Similar to the previous opportunities for changing car fleet usage, only trips performed during work days are considered as a potential bicycle trip. Limits for cycling distance and duration each day are used as described in the scope discussed previously. Only trips to and from a location in the Netherlands are considered in order to prevent forcing an employee to take his bike with him when driving to e.g. Italy for a business meeting.

Two scenarios for using the bicycle are considered: a rough scenario and a scenario that takes into account all trips that are performed during the day (similar to the train scenarios).

Scenario name	Assumptions
Bicycle rough	Employees make use of the bicycle when possible. When only part of the trips during the day are performable by bicycle, the other trips are performed using an available Capgemini car, or using public transport.
Bicycle getting home	When it is possible to travel from the home to the workplace by bicycle but not vice versa, or when one of the non-commuting trips is not performable by bicycle, all potential bicycle trips during that day are disqualified.

TABLE 10 BICYCLE SCENARIOS

In chapter 3 and 4 it was discussed that some trips might be incorrectly split due to the car powering off. It is therefore possible that someone travels 33 kilometres by car, but due to the car powering off twice during this trip, the dataset contains 3 trips of 11 kilometres each. This would then be incorrectly registered as three trips performable by bicycle. Therefore, all trips with less than 15 minutes of break in between are merged before looking for trips that could have been performed by bike.

How are the benefits of this transport change quantified?

It is assumed that using a bike does not results in CO_2 emission[26]. Furthermore it is assumed that every employee already has a bicycle, so the employer does not have to buy a bike for his employees. The expected benefits for using the bike are then simply the reduction in CO_2 emission and the costs reductions of using the lease cars less, as was already discussed previously.

APPROACH: CHANGE WORK LOCATION

Why consider this change in satisfying transport need?

Out of all performed trips, 8.35% were trips to a Capgemini office, where an employee stayed at this office for four hours or more before leaving again (chapter 4). It is hypothesized that employees might not always work at their nearest Capgemini office, perhaps because all of his colleagues work at a different office. If employees are encouraged to always use the nearest Capgemini office, this can result in less driven kilometres and the subsequent reductions in CO_2 emission and costs. Therefore, each trip to a Capgemini office is analysed in order to check whether another office might have been closer. However, this analysis should be handled with reserve. Employees probably visit a certain Capgemini office for a reason. For example, when a large meeting is held, the

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[25] Starting at roughly 30 cents per kilometre (after the start fee, € 2.20) and going down to approximately 2 cents per subsequent kilometre (with a maximum train ticket price of € 26.30 for a second class seat).

[26] This is not entirely true because building and maintaining the bicycle results in some CO_2 emission. However, for the sake of comparability these lifecycle emissions are note taken into account (CO_2 emission of producing and maintaining cars and trains are therefore also not taken into account).

distance to the Capgemini office for an individual employee is less important than the distance of the group to the office. No hard conclusions can be made using this analyses. However, this analysis can be used to justify further investigations into the office of choice of employees.

How are the trips identified that could potentially be performed differently?
All trips to a Capgemini office, where an employee stayed at this office for four hours or more before leaving again are selected. The distance between origin and the Capgemini office is then compared to the distance between the origin and all other Capgemini offices[27]. The difference between the chosen and the closest Capgemini office is then set as the potential reduction in travelled kilometres. Only trips during workdays are considered. Trips to the data centre (table 7) of Capgemini are excluded because the data centre is not a regular Capgemini office. It is hypothesized that employees who visit the data centre do so because they have business there that cannot be conducted somewhere else. Similar, the data centre is also not taken into account when searching for the closest Capgemini office.

How are the benefits of this transport change quantified?
Calculations of the environmental and financial benefits are done based on the reduction in driven kilometres as discussed previously.

APPROACH: USING THE SHARED CAR POOL OF CAPGEMINI

Why consider this change in satisfying transport need?
Capgemini has a number of cars available that employees can borrow for a day. These cars facilitate the travel need of employees whom do not have a car of their own (either lease or private). This last analysis does not change the employee travel behaviour. Instead, it identifies the trips that could have been performed by one of the cars in the shared car pool of Capgemini. This does not decrease the number of kilometres travelled by car. However, it does give insight into the potential increased usage of the Capgemini shared car pool. Employees might be persuaded to travel to a Capgemini office using public transport, or the bicycle. They can then use one of the Capgemini pool cars for their non-commuting business related travels.

How are the trips identified that could potentially be performed differently?
The trips in the lease car dataset are analyzed on a per car and per day basis. When a car visits a Capgemini office, the number of trips between that visit and the next Capgemini office visit are registered. The trips in between the two Capgemini office visits are classified as performable using the Capgemini shared car pool. A few restrictions are applied. Only trips during work days are counted because it might be harder to pick up or drop off Capgemini lease pool cars during the weekends. The first and subsequent visit to the Capgemini office should occur on the same day because the shared pool cars have to be returned to Capgemini at the end of the day. No restrictions are applied to the pickup and drop off Capgemini offices, so an employee can pick up a car at one office and drop it off at a different office.

How are the benefits of this transport change quantified?
No benefits are calculated for this change in travel behaviour because the number of driven kilometres by car do not change when using shared pool cars. Possible advantages of using the shared pool cars are discussed.

COMBINING OPPORTUNITIES FOR TRAVEL NEEDS SATISFACTION

Finally, an estimation is made of the expected total benefits achievable when combining the opportunities for changing travel need satisfaction. This analyses is performed using the knowledge acquired by analysing every opportunity in isolation.

[27] Note that this study does not actually use routing software to calculate the distance between an origin and a different Capgemini office. Instead to lease car dataset is searched for another car that performed a very similar trip (from a location close to the origin to the same Capgemini office). The distance travelled by this car is then set as the new distance travelled. In order to find accurate distances, the origins of the two trip should be within 5 kilometre radius of each other and the distance between the two origins is added to the new distance travelled.

5.3 Carpool opportunities

For the different carpool scenarios, a number of trips are identified as potentially carpoolable:

Scenario name	Number of carpool trips	Average number of cars going going in same direction	Possible reduction in trips	% of total trips	Possible reduction km's	% of total km's
Carpool rough	43,914	2.2	20,685	4.01%	979,659	4.29%
Carpool recurring trips	3,758	2.1	1,804	0.35%	80,484	0.35%
Carpool getting home	2,640	2.4	1,201	0.23%	48,663	0.21%

Table 11 Number of trips and their aggregated statistics that are potentially carpoolable for the different carpool scenarios. Results based on the trips performed during the 8 months contained in the dataset.

Table 11 contains a column titled “Number of carpool trips” and “Possible reduction in trips”. The first column represent the total number of trips that have another car travelling at the same time from and to roughly the same location, as described in the approach section. The second column represents the total number of reduced trips that can be achieved when all employees that can carpool, make use of this possibility.

The number of cars going in the same direction averages between 2.1 and 2.4 cars. This indicates that when a carpool opportunity occurs, often only two employees are driving in the same direction at the same time. Thus, employees do not frequently travel with dozens of other employees from the same location to another location at the same time. Carpooling will therefore have to be organised on an individual level in order for it to be successful.

A clear reduced carpool potential is seen when taking into account recurring trips, or carpooling with the restriction of getting back home again. Compared to “Carpool rough”, the recurring trips and getting home scenarios result in 93% and 94% less potential carpool opportunities respectively[28]. This reveals that when taking realistic usage scenarios into account, the carpool potential is much smaller than the initial analysis indicates.

Expressed in kilometres reduction, the “Carpool rough” scenario could achieve a reduction of almost 1 million lease car kilometres. However, for the more realistic carpool scenarios, the reduction in driven kilometres is much smaller. Expressed in percentage of total driven kilometres (table 2), the rough scenario achieves a reasonable reduction in kilometres (4.29%). However, the realistic scenarios result in insignificant reductions in driven kilometres when compared to the total driven kilometres. The potential of carpooling might therefore be smaller than initially anticipated.

[28] Calculated by comparing the number of carpool trips.

FIGURE 30 ORIGINS AND DESTINATIONS OF POTENTIAL CARPOOL TRIPS ACCORDING TO THE "CARPOOL ROUGH" SCENARIO. ORIGINS AND DESTINATIONS ARE AGGREGATED IN 10 KILOMETRE RADII IN ORDER TO IMPROVE READABILITY OF THE FIGURE. NUMBER OF CAR MOVEMENTS AVERAGED OVER NUMBER OF WORK DAYS.

Figure 30 indicates the carpool origins and destinations of the "Carpool rough" scenario. The carpool potential is mostly to and from Utrecht and Amsterdam. This is expected because the most business related travels are also to and from these "hotspots" (chapter 4).

The following beneficial effects are achievable in the most favourable case where every potential carpool is taken advantage of:

Scenario name	Reduction in lease car expenses	% costs reduction	CO_2 reduction	% reduction in CO_2
Carpool rough	€ 277,920	0.69%	356,960 kg	4.29%
Carpool recurring trips	€ 22,833	0.06%	29,327 kg	0.35%
Carpool getting home	€ 13,805	0.03%	17,732 kg	0.21%

Table 12 Beneficial effects achievable when carpooling. Benefits extrapolated to a full year and to the entire lease fleet.

When the carpooling opportunities are exploited, a cost saving and reduction in CO_2 emission can be achieved. Table 12 shows that €277,920 can be saved each year when every carpool opportunity is exploited. However, the more realistic scenarios show much lower cost savings. Compared to the expense incurred by Capgemini as the result of maintaining their lease car fleet[29], these cost savings are negligibly small regardless of which scenario is used. Tons of kilograms CO_2 can be saved by carpooling. However, for the realistic carpool scenarios, these reductions in CO_2 are negligible compared to the total CO_2 emission of the Capgemini lease fleet[30]. The "Carpool rough" scenario does result in a significant reduction in CO_2 emission. However, it is unlikely that this reduction is actually achievable.

The following is concluded based on the analyses of carpool opportunities:

[29] Capgemini spends 40 million on their car fleet every year (Knol, 2015).
[30] Total CO_2 emission calculated by multiplying total driven kilometres (22,829,934 km) by the average CO_2 emission per car (140 gram); extrapolated to a whole year and for the entire lease fleet .

- Initially carpooling seems to be a viable method for reducing the number of trips and total driven kilometres. However, when considering more realistic carpool scenarios, the reduction in number of trips and total driven kilometres is substantially less.
- Most carpool opportunities are trips going to or coming from Amsterdam or Utrecht.
- Carpooling results in beneficial financial and environmental effects. However, for the realistic usage scenarios, the financial and environmental benefits are small.
- The “Carpool rough” scenario does result in significant financial benefits. However, it is unlikely that these benefits are actually achievable.

The above analyses was also performed after merging trips with 15 minutes in between. This did not significantly change the conclusions made above.

5.4 TRAIN OPPORTUNITIES

For the different train scenarios, a number of trips are identified as potentially performable by train:

Scenario name	Number of trips performable by train	% of total trips	Possible reduction in car km's	% of total km's
Train rough	91,530	17.77%	4,404,688	19.29%
Train getting home	44,542	8.65%	2,295,593	10.05%

TABLE 13 NUMBER OF TRIPS AND THEIR AGGREGATED STATISTICS THAT ARE POTENTIALLY PERFORMABLE BY TRAIN FOR THE DIFFERENT TRAIN SCENARIOS. RESULTS BASED ON THE TRIPS PERFORMED DURING THE 8 MONTHS CONTAINED IN THE DATASET.

By taking the train when possible, 4,404,688 and 2,295,593 car kilometres can be avoided for the “rough” and “getting home” scenarios respectively. A great number of business trips are performable using the train instead of the car. By using the train more often, the total lease car kilometres can be reduced by a significant amount.

The difference between the rough scenario and the getting home scenario is smaller when considering taking the train compared to considering a carpool. This is due to the fact that there are more train stations in the Netherlands compared to potential carpools. The realistic usage scenario compared to the rough usage scenario results in a 51% decrease in the number of potential trips performable by train. Under the “Train getting home” scenario, significantly more trips can still be performed compared to the “Carpool getting home” scenario. Under realistic circumstances, intensifying train usage therefore looks more promising than carpooling.

A visualisation of the routes to and fro the different train stations is depicted in appendix H. However, specific routes in this visualisation are hard to identify due to the large number of train stations in the Netherlands. As an alternative, the top 5 most visited train routes are given next.

Station 1	Station 2	Total number of possible trips
Amsterdam Bijlmer ArenA	Utrecht Leidsche Rijn	1247
Amsterdam Bijlmer ArenA	Utrecht Zuilen	947
Amersfoort	Utrecht Leidsche Rijn	852
Utrecht Leidsche Rijn	Utrecht Zuilen	828
Utrecht Centraal	Utrecht Leidsche Rijn	799

TABLE 14 TOP 5 MOST USED TRAIN ROUTES WHEN LEASE CAR TRIPS ARE PERFORMED BY TRAIN INSTEAD. BASED ON THE “TRAIN ROUGH” SCENARIO

Station 1	Station 2	Total number of possible trips
Amsterdam Bijlmer ArenA	Utrecht Zuilen	683
Amersfoort	Utrecht Leidsche Rijn	496
Amsterdam Bijlmer ArenA	Utrecht Leidsche Rijn	459
Utrecht Leidsche Rijn	Utrecht Zuilen	393
Driebergen-Zeist	Utrecht Leidsche Rijn	392

TABLE 15 TOP 5 MOST USED TRAIN ROUTES WHEN LEASE CAR TRIPS ARE PERFORMED BY TRAIN INSTEAD. BASED ON THE “TRAIN GETTING HOME” SCENARIO

Table 14 & 15 show that the top 5 routes of trips performable by train either originate or are destined to Utrecht or Amsterdam. This was expected as these cities are most often visited by lease car (chapter 4).

The following beneficial effects are achievable in the most favourable case when every potential train ride is taken advantage of:

Scenario name	Reduction in travel expenses	% costs reduction	CO_2 reduction	% reduction in CO_2
Train rough	€ -306,458	-1.02%	396,422 kg	12.40%
Train getting home	€ -156,213	-0.52%	206,603 kg	6.46%

TABLE 16 BENEFICIAL EFFECTS ACHIEVABLE WHEN TAKING THE TRAIN. BENEFITS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

Table 16 shows that switching from using the lease car to taking the train actually costs Capgmini money. This is caused by the current travel compensation scheme that Capgemini uses. Currently, Capgemini offers employees with a lease car the possibility to travel using public transport free of charge. This means that when employees take the train instead of using their lease car, Capgemini needs to foot the bill of the resulting train ticket. The average price per kilometre of travel by train is 0.18 euro[31], whereas Capgemini reduces its travel expenses by 0.109 euro per lease car kilometre reduction. Thus Capgemini loses money when employees use the train instead of the car. However, this does not mean that promoting train usage is undesirable. Taking the train does result in significant carbon dioxide emission reduction.

The following is concluded based on the analyses of train opportunities:

- By using the train whenever possible, a great number of kilometres travelled by lease car can be reduced.
- Most trips performable by train travel to or from Amsterdam or Utrecht.
- Intensifying train usage results in additional financial costs instead of benefits in the current Capgemini lease scheme.
- Intensifying train usage results in a great reduction of the total CO_2 emission.

The above analyses was also performed after merging trips with 15 minutes in between. This did not significantly change the conclusions made above.

5.5 Cycling opportunities

For the different bicycle scenarios, a number of trips are identified as potentially performable by bicycle:

Scenario name	Number of trips performable by bicycle	% of total trips	Possible reduction in car km's	% of total km's
Bicycle rough	81,179	15.76%	435,988	1.91%
Bicycle getting home	25,615	4.97%	139,959	0.61%

TABLE 17 NUMBER OF TRIPS AND THEIR AGGREGATED STATISTICS THAT ARE POTENTIALLY PERFORMABLE BY BICYCLE FOR THE DIFFERENT BICYCLE SCENARIOS. RESULTS BASED ON THE TRIPS PERFORMED DURING THE 8 MONTHS CONTAINED IN THE DATASET.

By taking the bicycle when possible, 81,179 and 25,615 car trips can be avoided for the “rough” and “getting home” scenarios respectively. Although a number of car trips can be avoided by taking the bicycle, the resulting reduction in driven car kilometres is somewhat disappointing. This is due to the fact that only trips shorter than 12.5 kilometres are performable by bicycle per definition. Thus the average car trip kilometre reduction is smaller than the average car trip length over the whole dataset (44 km, table 2).

Origin	Destination	Total number of possible trips
Utrecht	Utrecht	15332
Amsterdam	Amsterdam	4380
Apeldoorn	Apeldoorn	2298
Eindhoven	Eindhoven	2136
Rotterdam	Rotterdam	2005

TABLE 18 TOP 5 MOST USED BICYCLE ROUTES. BASED ON THE “BICYCLE ROUGH” SCENARIO.

[31] The costs of each train ticket is calculated using the method described in the approach section. The 0.18 euro average price per kilometre is found in the following way: $\frac{total\ cost\ of\ train\ tickets}{kilometres\ performable\ by\ train}$.

Origin	Destination	Total number of possible trips
Utrecht	Utrecht	4764
Amsterdam	Amsterdam	954
Eindhoven	Eindhoven	938
Utrecht	Nieuwegein	837
Utrecht	Vleuten	764

TABLE 19 TOP 5 MOST USED BICYCLE ROUTES. BASED ON THE "BICYCLE GETTING HOME" SCENARIO

Table 18 & 19 show the top 5 cities with the highest bicycle trip potential. Utrecht and Amsterdam lead both lists. Apeldoorn and Eindhoven are both cities that have a Capgemini office. Employees living close to the office but who still drive to work are most likely the cause of the large number potential bicycle trips in Apeldoorn and Eindhoven. Rotterdam has a large number of employees both living and working there (figure 24), which results in a large bicycle potential. For the "Bicycle getting home" scenario, trips from Nieuwegein and Vleuten to Utrecht are also often performable by bicycle. These trips are possible because Nieuwegein and Vleuten are located directly beside Utrecht.

The following beneficial effects are achievable in the most favourable case when every potential bicycle ride is taken advantage of:

Scenario name	Reduction in travel expenses	% costs reduction	CO_2 reduction	% reduction in CO_2
Bicycle rough	€ 123,686	0.31%	158,861 kg	1.90%
Bicycle getting home	€ 39,706	0.10%	50,997 kg	0.61%

TABLE 20 BENEFICIAL EFFECTS ACHIEVABLE WHEN TAKING THE BICYCLE. BENEFITS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

The reduction in driven car kilometres results in a significant financial benefit and reduction in total CO_2 emission for the "rough" scenario. The "getting home" scenario results in much smaller benefits. Taking the bicycle results in both financial and environmental benefits (in contrary to taking the train). Also, under the more realistic usage scenario ("getting home"), considerably more CO_2 and cost reductions are achieved compared to the realistic usage scenarios for carpooling. Therefore, promoting bicycle usage is worth exploring further. Especially when taking into account the beneficial effects on employee health (De Hartog et al., 2010).

The following is concluded based on the analyses of bicycle opportunities:

- A number of trips can be performed by bicycle.
- The resulting potential reduction in driven kilometres is smaller than expected based on the number of potential bicycle trips.
- The cities of Utrecht and Amsterdam show the largest bicycle potential.
- Apeldoorn and Eindhoven also have a large bicycle potential. This is probably caused by the fact that Capgemini offices are also located there.
- By taking the bicycle, both financial and environmental benefits can be achieved.
- Promoting bicycle usage can result in financial, environmental and employee health benefits.

5.6 Working at different Capgemini offices

The following number of trips are identified as Capgemini office visits where a different Capgemini office was closer:

Scenario name	Number of trips not to closest office	% of total trips	Possible reduction in car km's	% of total km's
Closest office	27,868	5.41%	656,736	2.87%

TABLE 21 NUMBER OF TRIPS AND THEIR AGGREGATED STATISTICS TO CAPGEMINI OFFICES WHERE A DIFFERENT OFFICE WAS CLOSER BY. RESULTS BASED ON THE TRIPS PERFORMED DURING THE 8 MONTHS CONTAINED IN THE DATASET.

Table 21 shows that part of all trips performed could have been shorter by visiting a different Capgemini office. Out of all trips 5.41% is visiting a Capgemini office, different from the closest office. This number is especially high when considering that 8.35% of all trips visited a Capgemini location for more than 4 hours. Thus roughly

65%[32] of all (+4 hour) Capgemini office visits are potentially inefficient visits that could have been improved (travel distance wise) by visiting a different office.

Went to	Should have gone to	Total number of trips
Utrecht Leidsche Rijn	Utrecht Papendorp	6188
Utrecht Leidsche Rijn	Amsterdam Zuid Oost	5616
Utrecht Papendorp	Utrecht Leidsche Rijn	3690
Utrecht Leidsche Rijn	Apeldoorn	2793
Utrecht Papendorp	Amsterdam Zuid Oost	1789

TABLE 22 TOP 5 CAPGEMINI OFFICE WHERE A DIFFERENT OFFICE WAS CLOSER BY

Table 22 shows the top 5 Capgemini offices where a different office was closer by. A number of things are noticed: Utrecht Leidsche Rijn is identified as an office that is often visited when a different office is closer by. Hower, Utrecht Papendorp is also often visited when Utrecht Leidsche Rijn is closer. This is probably caused by the fact that a number of employee trainings are taught at the Capgemini Papendorp office. Other notable locations are Amsterdam Zuid Oost and Apeldoorn[33], both are not visited even though they are the closest office. Table 22 shows a clear preference: Capgemini employees visit the head office at Leidsche Rijn often, even when this is not the closest office. Two reasons for this behaviour are hypothesized. First, it is conceivable that employees like working at the head office out of habit, and therefore visit this location often. More likely however, the head office is visited often because it is the largest office, most employees work there, and thus meetings (formal and informal) are logistically easier to arrange at the head office[34]. Employees who work at Leidsche Rijn out of habit might be persuadable to work at a different office instead. However, employees who work at Leidsche Rijn out of necessity are unlikely to change their location of labour. The following financial and environmental benefits should therefore be regarded as the hypothetical best achievable result (ceiling) when employees are encouraged to visit the closest office. More research is required in order to more accurately assess the expected benefits of this travel needs satisfaction opportunity.

Scenario name	Reduction in travel expenses	% costs reduction	CO_2 reduction	% reduction in CO_2
Closest office	€ 186,309	0.47%	239,296 kg	2.88%

TABLE 23 ROUGH APPROXIMATION OF BENEFICIAL EFFECTS ACHIEVABLE WHEN EMPLOYEES ARE ENCOURAGED TO WORK AT THE NEAREST CAPGEMINI OFFICE. BENEFITS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

Financial and environmental benefits are achievable when encouraging employees to work at the nearest Capgemini office. However, these benefits will probably never be realised due to the limitations as described above. An accurate assessment of the expected benefits of encouraging employees to work at the nearest Capgemini office cannot be made using the currently available information. Further research is recommended.

The following is concluded based on the analyses of working at the closest office:

- A number of trips can be shortened when employees are encouraged to work at the nearest Capgemini office.
- Most visits to a Capgemini office are visits to a location other than the closest Capgemini office.
- Some financial and environmental benefits might be achievable when encouraging employees to work at the nearest Capgemini office.
- However, currently an accurate assessment of the expected benefits of encouraging employees to work at the nearest Capgemini office cannot be made.

[32] $\frac{5.41\%}{8.35\%} \times 100 = 64.79\%$

[33] Eindhoven is also often not visited even though it is the closest office. However, this location fell just outide of the top 5 locations.

[34] Meetings are logistically easier to arrange at the head office because, among other things, meeting rooms and plenty of workspaces are available there.

5.7 Trips performable using shared car pool

The following number of trips are identified as trips that start and end at a Capgemini office within a workday:

Scenario name	Number of trips to and fro Capgemini	% of total trips	Total car km's	% of total km's
Shared car pool	9,624	1.87%	233,519	1.02%

TABLE 24 NUMBER OF TRIPS AND THEIR AGGREGATED STATISTICS THAT START AND END AT A CAPGEMINI OFFICE DURING A WORKDAY. BENEFITS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

On average, 0.4 trips are performed between leaving the Capgemini office in the morning and returning to the Capgemini office in the evening. This indicates that in general trips potentially performable using a shared car will be used to visit a single destination before returning to Capgemini again. However, a number of trips also visit more than one location between Capgemini visits.

So why even look at the potential of the Capgemini shared cars? When a shared car can be used to perform all non-commuting business related trips during a day, the employee in question can then be more easily persuaded to commute by carpool/train/bicycle to a Capgemini office, and then use one of the available shared cars for his transport needs during the day.

The following is concluded based on the analyses of trips performable using the Capgemini shared car pool:

- When a trip starts and ends at a Capgemini office over the course of the day, on average, only one location is visited between the two Capgemini office visits.
- Promoting the usage of the Capgemini shared cars might encourage employees to commute without using their lease car. However, not that much trips are performable by shared car to begin with.

5.8 Combining opportunities for travel needs satisfaction

A number of different opportunities to change travel needs satisfaction were discussed in this chapter. The financial and environmental benefits of the opportunities are summarized below.

Scenario name	Reduction in travel expenses	% costs reduction	CO_2 reduction	% reduction in CO_2
Carpool rough	€ 277,920	0.69%	356,960 kg	4.29%
Carpool recurring trips	€ 22,833	0.06%	29,327 kg	0.35%
Carpool getting home	€ 13,805	0.03%	17,732 kg	0.21%
Train rough	€ -306,458	-1.02%	396,422 kg	12.40%
Train getting home	€ -156,213	-0.52%	206,603 kg	6.46%
Bicycle rough	€ 123,686	0.31%	158,861 kg	1.90%
Bicycle getting home	€ 39,706	0.10%	50,997 kg	0.61%
Closest office	€ 186,309	0.47%	239,296 kg	2.88%

TABLE 25 FINANCIAL AND ENVIRONMENTAL BENEFITS OF ALL OPPORTUNITIES FOR CHANGES IN TRAVEL NEEDS SATISFACTION. BENEFITS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

A yearly cost reduction of €50,000 and/or a yearly reduction of 100,000kg CO_2 emission is deemed as the minimum expected benefit in order to consider changing the Capgemini mobility policy according to the Director Facilities (Knol, 2015). Table 25 shows that all four opportunities for travel needs satisfaction have the potential to change the Capgemini mobility policy[35].

The Capgemini mobility policy can be changed to fulfil two conflicting interests. Either financial benefits or environmental benefits can be pursued. When financial benefits are pursued, travelling by train should be excluded as an opportunity for satisfying the travel needs because this opportunity actually costs Capgemini money. However, when pursuing environmental benefits, travel by train is a viable way to reduce the CO_2 emission. Therefore the expected benefit of applying combinations of opportunities for satisfying travel needs are discussed both when financial or environmental benefits are pursued.

[35] The fifth opportunity for travel needs satisfaction, using a shared car, is expected to not result in financial or environmental benefits. However, by applying the shared car, employees can more easily use the trains, bicycles and carpools to satisfy all their travel needs during the day, as will be shown below.

Table 25 cannot be used to get an accurate estimation of the total benefits achievable when combining opportunities for satisfying travel needs. Adding up the “rough” scenarios results in counting some trips double. Moreover, the rough scenario is deemed as unrealistic because employees might not be able to satisfy all of their travel needs when considering the “rough” scenario. The more realistic scenarios (“getting home” and “recurring trips”) can also not be added up to get an estimation of the total achievable benefits. The problem of double counting trips is still an issue for the more realistic scenarios. Moreover, the more realistic scenarios do not take into account the possibility of combining travel modes. For example, taking a train to work, but taking a carpool back home. Therefore, a new analysis, using the results of the “rough” and “getting home” scenarios is performed to estimate the possible benefits of pursuing financial or environmental gains. This analysis is based on using both a single transport mode, or combinations of transport modes during the day.

An estimation of the achievable financial or environmental benefits is made by allocating all trips performed by a certain lease car during a single day to one or more new transport opportunities. This is done using the allocation rules shown in table 26.

Pursuing financial benefits
1. All trips by bicycle
2. All trips by carpool
3. Trips first by shared car, remainder by bicycle
4. Trips first by shared car, remainder by carpool

Pursuing environmental benefits
1. All trips by bicycle
2. All trips by train
3. All trips by carpool
4. Trips first by train, remainder by bicycle
5. Trips first by train, remainder by carpool
6. Trips first by shared car, remainder by train
7. Trips first by shared car, remainder by bicycle
8. Trips first by shared car, remainder by carpool
9. Trips first by train, then by carpool, then by shared car

TABLE 26 ALLOCATION RULES FOR ESTIMATING ACHIEVABLE TOTAL FINANCIAL OR ENVIRONMENTAL BENEFITS[36]

An example of applying the allocation rules when pursuing environmental benefits: All trips performed on Tuesday 28 July by car #31412 are analysed. First, it is checked whether all trips during that day are also performable using the bicycle (rule 1). If all trips are performable by bicycle, the corresponding financial and environmental benefits are added to the total expected benefits. When all trips cannot be performed by bicycle, it is checked whether all trips are performable using the train (rule 2). This continues until rule 9 is rejected. When this is the case, it is concluded that no alternative transport possibilities exist. Pursuing financial instead of environmental benefits follows a similar logic.

The rule hierarchy in table 26 were constructed on a number of principles:

- Taking the train does not result in financial benefits.
- Usage of only one transport mode (other than a lease car) is preferred over combinations of transport modes.
- A bicycle can be taken with you in the train.
- When a shared car is used, it is used for all trips in between the first and subsequent visit to a Capgemini office.
- A bicycle can be used in combination with a shared car.
- A bicycle cannot be taken with you in combination with a carpool.
- Travelling by bicycle is preferred over travelling by carpool because the bicycle has larger benefits.
- Travelling by train is preferred over travelling using a shared car because the train has larger environmental benefits.
- Travelling by carpool is preferred over travelling using a shared car because the carpool has larger benefits.
- All trips during the day need to be performable using a transport mode other than the lease car.

[36] Note that the working at the closest Capgemini office opportunity is not included in the allocation rules. As discussed previously, the feasibility of this opportunity is questionable. Therefore, this opportunity was left out.

By considering using different transport modes during the day, the following changes in travel satisfaction can be achieved:

Rule	Pursuing financial benefits	Pursuing environmental benefits
All trips by bicycle	169	169
All trips by train		202
All trips by carpool	9	4
Trips first by train, remainder by bicycle		80
Trips first by train, remainder by carpool		84
Trips first by shared car, remainder by train		2
Trips first by shared car, remainder by bicycle	2	1
Trips first by shared car, remainder by carpool	10	0
Trips first by train, then by carpool, then by shared car		6
Total:	190	548

TABLE 27 AVERAGE NUMBER OF EMPLOYEES THAT CAN USE THE COMBINATIONS OF TRAVEL MODES TO SATISFY THEIR TRAVEL NEEDS ON A WORK DAY. RESULTS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

Table 27 depicts the average number of employees who can satisfy their travel need using travel modes besides their lease car on a workday. A difference is observed between the number of employees when pursuing financial benefits and the number of employees when pursuing environmental benefits. This difference is caused by the fact that train usage is not taken into account when pursuing financial benefits. Assuming that approximately 3000 employees use the 3000 cars in the Capgemini lease fleet, then on average each work day 6.3% and 18.3% of the lease car using employees could have used different transport modes resulting in financial or environmental benefits respectively.

	Pursuing financial benefits			Pursuing environmental benefits		
Transport mode	**Km's**	**€**	**CO_2**	**Km's**	**€**	**CO_2**
Bicycle	362,227	€ 39,482.69	50,712 kg	479,865	€ 52,305	67,181 kg
Train				6,517,518	€ -435,521	586,577 kg
Carpool	81,221	€ 8,853.06	11,371 kg	45,120	€ 4,918	6,317 kg
Shared car	251,124			182,926		
Total:	694,572	€ 48,336	62,083 kg	7,225,429	€ -378,298	660,075 kg

TABLE 28 KILOMETERS (REDUCTION), ESTIMATED REDUCTION IN COSTS, AND ESTIMATED REDUCTION IN CO_2 EMISSION WHEN COMBINING TRANSPORT MODES. RESULTS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

Table 28 shows how much lease car kilometres, lease costs and CO_2 emission can be reduced by satisfying employee travel needs using alternative transport modes. Note that the depicted "reduction" in lease car kilometres by using a shared car, does not result in any benefits. This is caused by the fact that the reduction in lease car kilometres is counteracted by the increase in shared car kilometres. The most lease car kilometres are reduced by taking the train instead. A great reduction in CO_2 emission can be achieved by taking the train more often. However, taking the train more often also results in an increase in the travel expenses. By using the bicycle more often, the lease car kilometres can be reduced by a decent amount. Increased usage of the bicycle results in both a reduction of the travel expenses and a reduction in the CO_2 emission (regardless of which benefits are pursued). In order to compare the results of pursuing financial benefits or environmental benefits, the results of table 28 are put into perspective in table 29.

Goal	Reduction in travel expenses	% costs reduction	CO_2 reduction	% reduction in CO_2
Financial benefits	€ 48,336	0.12%	62,083 kg	0.75%
Environmental benefits	€ -378,298	-0.95%	660,075 kg	7.93%

TABLE 29 (RELATIVE) FINANCIAL AND ENVIRONMENTAL BENEFITS. BENEFITS EXTRAPOLATED TO A FULL YEAR AND TO THE ENTIRE LEASE FLEET.

When pursuing financial benefits, up to € 48,336 can be saved per year by changing the way travel needs are satisfied. Beside financial benefits, a CO_2 reduction of 62,083 kg is also achieved when pursuing financial benefits. The financial benefit achievable is below the €50,000 yearly travel cost reduction set as the minimum by the Capgemini Director of Facilities. The accompanying environmental benefit of 62,083 kg is also below the

100,000kg CO_2 emission reduction threshold. Based on these results, no significant financial benefit can be achieved by changing the way employee travel needs are satisfied.

When pursuing environmental benefits, significant reductions in CO_2 emissions do seem to be feasible. Up to 660,075 kg CO_2 emission can be reduced per year by changing travel mode. However, this CO_2 emission reduction comes with the price tag: an increase of € 378,298 in travel expenses per year. Thus, for every euro spent, 1.74 kg of CO_2 emission can be reduced. When only the train CO_2 emission and increase in travel expenses are taken into account, every euro spent results in a reduction of 1.35 kg CO_2.

A few remarks about the analyses performed in this paragraph:

Note that these reductions don't take into account the willingness of employees to change their travel behaviour. The actual realizable environmental and financial benefits depend on the participation of the employees.

Also note that the order of the rules in table 26 affect the trip allocation and the resulting benefits. For example, when trips during the day are allocated to trains and bicycle, these trips can no longer be performed by carpool and shared car, even though that also might have been a possibility. Thus, there exists interdependence between the order of the rules and the number of allocated trips to the different transport modes. Assuming that the rules shown in table 26 are in fact an exhaustive rule sets[37] (so new other rules can be added), then a total 24 and 362880 possible arrangements of the rules[38] exists for pursuing financial or environmental benefits respectively. The program that allocates the trips using the rule set takes approximately 6 hours to run. Thus, running different orders of rules will take a long time. Therefore, only the rule sets as described in table 26 are used to allocate trips. It is expected that changing the rules shown in table 26 will not significantly increase the number of trips performable using alternative transport modes because the rule sets were designed to result in as much alternative transport opportunities as possible while keeping in mind realistic usage of different transport modes.

The following is concluded:

- When pursuing financial benefits, a lot less travels can be performed using alternative methods of transportation compared to pursuing environmental benefits. This is caused by the fact that using the train more often actually increases the travel expenses for Capgemini.
- On average, each work day, 6.3% and 18.3% of the lease car using employees could have used different transport modes that would have resulted in financial or environmental benefits respectively.
- By pursuing financial benefits, up to € 48,336 can be saved per year by changing the way travel needs are satisfied. The financial benefit achievable is below the €50,000 yearly travel cost reduction threshold. No significant costs saving can therefore be achieved by changing employee travel mode.
- Up to 660,075 kg CO2 emission can be reduced per year by changing travel mode (a significant amount). Put in perspective, this means the CO_2 exhausted by the lease car fleet can be reduced by 7.93%
- The reduction of CO_2 comes with a price tag of € 378,298 per year due to the increase in train travel costs.
- Thus, for every euro spent, the CO2 emission can be reduced by 1.74 kg.

5.9 Expected tradeoffs

The analyses of the five changes in satisfying employee travel needs discussed above focused on the beneficial effects for Capgemini by changing the way business travels are performed. This section will qualitatively discuss the possible (negative) side effects of changing the way employee travel needs are satisfied.

[37] Table 26 does not contain the exhaustive rule set. For example, transport by bus is not taken into account. Moreover, in certain cases usage of the train might actually result in a net financial benefit when for example train usage is combined with using the bicycle. This was not taken into account when pursuing financial benefits.

[38] $4! = 4 \times 3 \times 2 \times 1 = 24; 9! = 9 \times 8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1 = 362880$

<u>Negative side effect: Increased travel time</u>

Opportunities likely affected by this:

- Carpooling
- Taking the train
- Cycling

Carpooling, taking the train or cycling can result in an increase in travel time. When carpooling, a detour from the quickest route to the destination is necessary in order to pick up and drop off the carpool passenger. As explained in the scope at the beginning of this chapter, this will result in some additional travel time (up to a maximum of 36 minutes).

Taking the train has the potential of traveling faster than using the car because traffic jams can be avoided. However, in 2015 the Dutch railway registered 2.941 malfunctions, resulting in travel delays between 0 and 30 minutes (21%), 30 to 60 minutes (18%), 60 to 90 minutes (13%), or even longer delays (48%) (Rijden de Treinen.nl, 2016). Moreover, when transferring to a different train, transfer time is an ever present source of travel delay. Therefore, taking the train might result in an increase in travel time.

Cycling to work instead of using the car can result in shorter travel times if taking the car mean getting stuck in traffic. However, when the route is not prone to traffic jams, then cycling to work will most likely be slower than taking the car due to the limited maximum velocity of a bicycle.

It is assumed that employees try to minimalize their travel time for business purposes. The above mentioned sources of delay might therefore discourage employees from changing their travel behaviour. Moreover, non-commuting business travels often occur during work time. Increased travel time might therefore result in an increase in unproductive hours of the employees. The opposite, however, is also possible when employees work during their non-commuting business travels (e.g. working in the train, or performing calls during carpools).

Because the travel time of every trip depends on a large set of factors (time of day, route taken, proneness to travel jams, transfer times, train routes prone to malfunctions, shortcuts performable by bicycle, etc.), it is very hard to calculate the expected travel time when changing the way travel needs are satisfied. Therefore, this study did not quantify the expected increase or decrease in travel time. Change in travel time should be taken into account before encouraging employees to change their travel behaviour.

<u>Negative side effect: vulnerable to external forces</u>

Opportunities likely affected by this:

- Carpooling
- Taking the train
- Cycling
- Working at closest Capgemini office
- Using shared cars

Every proposed opportunity for changing the way travel needs are satisfied result in a change in vulnerability to external forces. When carpooling, the employee is dependent on the availability of the carpool. Assuming a carpool to and from the workplace was arranged beforehand, then a change in plans[39] during the day can result in an employee losing his ride (e.g. back home).

Trains are notoriously often delayed, or not running altogether (Rijden de Treinen.nl, 2016). When traveling by train, the employee is therefore vulnerable to the whims of train availability. Furthermore, operation performed

[39] E.g. a meeting running late, an ad hoc client visit, or the necessity to work overtime.

to the rail network (planned or unplanned) can result in increased travel times or even an inability to reach the destination using the train for up to multiple years. When using their own lease car, employees are at least guaranteed that they will be able to reach their destination, and all destinations after that, during the day[40].

One important external factor influencing the usability of the bicycle is the weather. Weather conditions can result in an inability to reach the destination. The weather conditions can be predicted to a certain degree, but this means that an employee has to keep a close watch on the weather predictions. Furthermore, the accuracy of predictions is sometimes lacking, resulting in unexpected weather unsuitable for using the bicycle to travel for business.

It has already been discussed that working at the closest Capgemini office might not be feasible. External forces influencing the ability to work at the closest office are for example: Meetings held at other offices, collaboration with colleagues whom all have different closest office or unavailability of workspaces at the smaller offices.

When depending on the shared Capgemini cars, car availability is important. Assuming numerous people use the shared cars, then when a shared car is required due to an unforeseen travel need, it is conceivable that no shared car is available. Reserving cars beforehand is not always possible when unforeseen circumstances occur.

Negative side effect: flexibility

Opportunities likely affected by this:

- Carpooling
- Taking the train
- Cycling
- Using shared cars

Closely related to vulnerability to external forces, flexibility is also affected when the way travel needs are satisfied is changed. Traveling using a carpool limits an employee from traveling during the day to non-carpool locations, going home early or late, changing travel plans mid-day, etc.

Traveling by train limits the employee to traveling according to the train timetable. Moreover, taking baggage with you is somewhat limited when taking the train. Taking the train does however enable an employee to work while traveling.

When travelling using the bicycle to a location other than a Capgemini office, all subsequent trips during that day also have to be performable by bicycle, or the employee has to cycle back home to get access to a car. Transportation by bike also limits the baggage transport possibilities.

When using one of the shared cars, the car has to be handed in at the end of the day. Driving straight home after a workday is therefore not possible any more. Vice versa, driving straight to work in the morning is also hard because the shared car first has to be picked up from the Capgemini office.

Negative side effect: Employee agitation

Opportunities likely affected by this:

- Carpooling
- Taking the train
- Cycling
- Working at closest Capgemini office
- Using shared cars

[40] Apart from acts of god obstructing travel by car. It is also assumed the car does not break down (often). However, lease cars often have excellent maintenance service, thus break downs are prevented as much as possible.

All proposed changes in satisfying the transport needs result in one or more negative side effects. This can lead to agitation of the employees. Appendix C discusses the company car functionality. One of the functions of a company car is compensation for the work employees perform for their employer. Changing the access to their company cars might be perceived by employees as a reduction of their compensation for their work. It is hypothesized that for some employees access to their lease car is important enough to consider changing employer when their lease car conditions are changed. This is undesirable for Capgemini because replacing employees can result in significant costs (Boushey & Glynn, 2012).

The following is concluded based on the qualitative analyses of the expected trade-offs when changing the way travel needs are satisfied:

- Changing the way travel needs are satisfied can result in increased travel times, vulnerability to external forces, and a reduction in travel flexibility.
- Changes in the access to company cars might be perceived by employees as a reduction of their compensation for their work. This might result in employees leaving the firm, which results costs in order to replace these employees.
- Whether the benefits outweigh the negative effects should be assessed on a per case basis.

Note that appendix C states that the company car also functions as a status symbol (appearance). Changing the usage of company cars can therefore change the company image. However, this does not necessarily have to be a bad thing. Changing the company image from petrol powered to more ecological responsible can affect the competitiveness and legitimacy of a company (Bansal & Roth, 2000).

5.10 Conclusions

This chapter analysed and discussed the expected big wins in changing the way travel needs are satisfied. Five opportunities for changing travel needs satisfaction were proposed: Carpooling, using the train, using the bicycle, encouraging employees to work at the closets Capgemini office, and using a shared car. Looking at the opportunities for changing travel needs satisfaction in isolation, a number of things are observed. Carpooling shows potential as a travel alternative. Up to 4.01% of all lease car trips could also have been performed using a carpool. However, when taking more realistic usage scenarios in account, where an employee needs to perform every trip during the day using a carpool, or when carpools need to be predictable, little potential carpools are found. Carpooling might therefore only be interesting when combined with other transport opportunities (more about this below). More intensive usage of the train shows the highest potential. Up to 17.7% of the lease car trips could have also been performed using the train. This does, however, results in an increase in travel expenses. When all trips during the day need to be performable using the train, 8.65% of all trips are still performable by train. The bicycle also shows promise in substituting the lease car with 15.76% of the lease car trips that have the potential to be performable by bicycle. When every trip during the day need to be performable by bicycle, 4.97% of all trips can still be performed by bike. Up to 5.41% of all trips could have been shortened by visiting a different Capgemini office. However, the possibility to shorten these trips depend greatly on the ability of the employees to actually change their location of labour. Therefore, the expected benefits of this opportunity is regarded with some reserve. Further research is required. Up to 1.87% of all lease car trips could have been performed using a shared pool car instead. However, this does not result in any beneficial effect when this travel opportunity is not combined with other travel opportunities. Studying the opportunities in isolation revealed that taking only the train or only the bicycle during the whole day will result in the largest trip reduction for Capgemini. Studying the opportunities in isolation also revealed that carpooling or using shared cars is only interesting when combined with other travel opportunities. The uncertainty about the feasibility of visiting different Capgemini offices limits the conclusions that can be made with certainty about this opportunity.

When looking at combination of travel opportunities (table 27), it is revealed that out of all the trips that can be performed differently, most trips are likely performed using either only the bicycle (169 employees per day on average can use their bike instead of their lease car) or only the train (202 employees per day) the whole day. Combining the train and bicycle during the day also results in a number of alternative trip possibilities (80 employees per day). Using carpools in combination with trains has a potential of roughly equal size (84 employees per day). Using a shared car in combination with any other travel opportunity resulted in only little travel alternative possibilities (less than 20 employees per day). Thus, carpooling enables more employees to use alternative transport possibilities than using shared cars. The potential of using shared cars more intensively is therefore deemed small. Regardless, the big winners for alternative transport opportunities are the bicycle and the train.

Combining the travel opportunities can result in both financial and environmental benefits. When financial benefits are pursued, 48,336 euro cost reduction per year is achievable, which is below the set threshold of 50,000 euro cost reduction per year. Therefore, no significant financial benefits can be achieved by changing the way travel needs are satisfied. When environmental benefits are pursued, the CO_2 emission can be reduced by 660,075 kg per year at the costs of 378,298 euro per year, a significant reduction. Note that these reductions don't take into account the willingness of employees to change their travel behaviour. The actual realizable environmental and financial benefits depend on the participation of the employees.

Beside financial and environmental benefits, secondary benefits like an increase in productive time (when employees work in the train, or during carpools) or beneficial employee health effects (when employees use the bike more often) are expected. However, changing the way travel needs are satisfied can result in increased travel times, vulnerability to external forces, and a reduction in travel flexibility. It might also convince employees to change jobs. It is recommended to assess whether the benefits outweigh the negative effects on a per case basis.

6. Offering mobility solutions

6.1 Introduction

This study focuses on Capgemini in order to discover the opportunities and expected benefits of changing from providing company cars to facilitating employee mobility. This chapter discusses whether changing from providing company cars to facilitating employee mobility is a feasible option for Capgemini. After that, the expected knowledge gains achievable at other companies by analysing the, for billing purposes collected, business related travel data are discussed.

6.2 Facilitating mobility not cars

Capgemini is currently primarily focussed on providing employees with lease cars. It is hypothesised that switching to providing employees a mobility solution instead of a lease car could improve the efficiency of employee transportation. Based on the analyses performed during this study, an estimation is made about the benefits for Capgemini when switching from offering cars to offering mobility solutions.

The analyses of the Capgemini travel patterns revealed that the company cars are primarily used for commuting. When lease cars are only used to commute, the potential for offering mobility instead of cars is increased. Recurring trips to origin-destination combinations offer a number of mobility facilitating opportunities (e.g. taking the train, or offering shuttle busses between two frequently visited locations). However, analyses also revealed that a significant portion of trips (23%, chapter 3) are probably non-commuting business related trips. These trips require flexible transport solutions. The most flexible transport solution is using your own lease car. Geographically, a centralization of employees occurs during work hours and a decentralization outside of work hours. Centralization of employees makes it easier to offer mobility solutions other than lease cars. When employees are conglomerated, mobility solutions like shared cars are easier to arrange. Moreover, conglomeration of employees occurs in city centres, making it easier to travel using the public transport network. Decentralisation of employees outside of business hours requires mobility solutions that are able to tend to a large number of (decentralized) destinations. The Capgemini lease cars are used to visit a great number of unique locations. Only 4% of the entire car fleet visit 10 unique locations or less. 79% of the lease fleet visited between 11 and 52 unique locations (chapter 3). Thus, the (lease) car is the mobility solution that can tend to the largest number of decentralised destinations. A large number of employee movements never leave the city they start in. Travels that never leave the city are ideal for offering mobility solutions other then lease cars. A city centre often has a good public transport network and travelling by bicycle might also be a feasible transport solution. Based on the analysis of the employee travel patterns, offering mobility solutions instead of lease cars might be a viable policy for a number of employees (employees moving to and fro city centres, or who travel without leaving city centres).

In chapter 5 the potential travel improvements are analysed. Five opportunities for changing the way travel needs are satisfied, are discussed. All five opportunities are examples of mobility solutions other than proving lease cars. The train or bicycle are the primary transport modes that have the potential to satisfy a number of lease car trips. When pursuing financial or environmental benefits, respectively 32,015 and 88,745 trips can be performed without using the employee lease car[41]. Put in perspective, respectively 6.2% and 17.2% all performed trips during the 8 months for which data was available can be performed using alternative travel modes. Thus, based on the results of this study, the majority of lease car trips are still only performable using a lease car.

Based on the analyses of the results of chapter 3, 4 and 5, this study did not reveal any significant benefits for Capgemini by switching from offering lease cars to offering mobility. It seems contra productive to offer mobility instead of cars when the majority of all business trips most likely need to be performed by lease car regardless of the mobility policy. Capgemini might be better off to continue to offer lease cars to its employees as the baseline, and then promote usage of bicycle and train for its environmental and health benefits. Note that some other mobility policy changes might also reduce the lease car usage of Capgemini employees. Currently carpooling is not registered. Registering employees who carpool, and perhaps offering some financial benefits for carpooling

[41] These numbers are not extrapolated to the entire lease car fleet or to an entire year.

might reduce the total driven lease car kilometres (depending on employee willingness to carpool). Promoting the availability of the Capgemini shared cars might also convince employees to use their lease cars less.

The analyses performed in chapter 3, 4 and 5 is used to identify factors influencing whether offering mobility instead of cars is preferable:

Facilitate mobility	**Offer cars**
▪ Mostly commuting business travels	▪ Significant number of non-commuting trips
▪ Limited number of places where business is conducted	▪ Great variety of places where business is conducted
▪ Predictable travel needs	▪ Unpredictable travel needs
▪ Business conducted at or near city centres	▪ Business conducted decentralized ▪ Business conducted far from public transport nodes
▪ Business conducted near public transport nodes	
▪ Employees living in clusters near each other and in city centres	▪ Employees living decentralized
▪ Short stable commuting distance	▪ Longer commuting distances and length of commute varies in time
▪ Work can be performed anywhere	▪ Work has to be performed at fixed locations
▪ Travel need within the borders of a country	▪ International travel need
▪ Facilitating mobility results in financial benefits	▪ No significant financial benefits achievable by facilitating mobility.
▪ Facilitating mobility results in environmental benefits	▪ No significant environmental benefits achievable by facilitating mobility.

TABLE 30 FACTORS INFLUENCING WHETHER OFFERING MOBILITY INSTEAD OF CARS IS PREFERABLE.

Table 30 shows the factors that influence whether offering mobility or offering cars is preferred. This table can be used to asses quick and dirty whether a company might benefit from changing its mobility policy. A description of a more thorough mobility policy analysis, performable at other companies, is given below.

6.3 General applicability of lease car data analysis

Companies with a lease car fleet usually register the business related travels of their employees for billing purposes. Thus travel data of employees is often available for these companies. This data can also be used to discover the opportunities and expected benefits of changing the company policy (focussing more on offering mobility and less on providing cars). In this study, as an example, the registered lease car trips of Capgemini were used to discover what benefits are expected when offering mobility instead of cars. The same analysis can also be applied to other companies as will be explained below.

The registered business related travels have to contain a number of data entries in order to perform every analyses in this study:

- Unique identifier for each car (e.g. a plate number).
- Time of trip departure and arrival
- Location of trip departure and arrival (either GPS coordinates or postcodes)
- Distance travelled during the trip

Other datasets that are consulted:

- The GPS coordinates of the train stations
- Possible routes between train stations
- The GPS coordinates of the company offices
- (Potentially) table converting postcode to GPS coordinates.

Note that little data actually has to be gathered in order to perform the analyses. The GPS coordinates of the train stations in the Netherlands and a table that converts the Dutch postcode to GPS coordinates are publically available. Therefore, little effort is required to gather the necessary data for other Dutch businesses. It is unclear whether the additional datasets are also publicly available in other countries. An assessment of the publically available data should be made prior to analysing the business trip dataset.

When the necessary data is available, this data can be used to analyse:

- At what time of day most employees are on the road
- Usage of the lease cars during the week
- The length distribution of the business trips
- The duration distribution of the business trips
- How long the lease cars are parked
- Where the lease cars are parked
- What locations are visited using the lease cars and with what frequency

This information is then used to answer questions like:

- Is the lease car primarily used for commuting or for non-commuting trips?
- Which trips could have potentially been carpooled?
- Which trips could have been performed using the public transport network?
- Which trips could have been performed by bicycle?
- Which trips could have been performed using a shared car?
- Are employees working at their nearest business office?
- Are there other alternatives to using the car to satisfy the employee travel needs?
- How can the opportunities for changing the way travel needs are satisfied be combined?
- What costs and benefits can be achieved by changing the way travel needs are satisfied?
- What policy changes are required to achieve those benefits?

Answering these question will reveal the potential change in employee travel behaviour when switching from providing cars to providing mobility. Regardless whether offering mobility is an option or not, valuable information about employee travel patterns is gained from analysing the billing data, as was also shown in this study[42].

[42] For instance, it was suspected by the Capgemini Director Facilities that a large number of employees live in Amsterdam and work in Utrecht and vice versa. The travel pattern analysis showed that actually only a small number of people travel from Amsterdam to Utrecht and vice versa each day.

7. CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

In this study a method for analyzing travel patterns of company car users using the already collected employee travel data was developed. This methods was then used to discover the opportunities and expected benefits of switching from providing cars to a mobility facilitating company policy for the Dutch Capgemini branch. In order to discover the opportunities and expected benefits of changing the Capgemini (Dutch branch) company policy, four research questions were answered. These research questions are discussed below.

1. What employee travel patterns can be found in the Capgemini (Dutch branch) employee travel data?
An overview of the travel behaviour of the (lease car using) Capgemini employees was made by analyzing the timing, recurrence and origins/destinations of the lease car trips. The Capgemini lease cars are primarily used for commuting, but non-commuting business trips also frequently occur. The lease cars are not used every work day. Trips are overwhelmingly performed within the Netherlands. Although a large number of unique locations are visited, a relative small amount of origin/destination combinations are frequently visited. A conglomeration of cars occurs during business hours, decentralization of cars occurs outside of business hours. Also, a number of recurring car travels never leave the city they start in. Using only the collected travel data, a quite comprehensive overview of the employee travel patterns has been made.

2. How can the employee travel data be used to improve Capgemini's (Dutch branch) business transport of employees?
Using the employee travel data, an assessment was made of alternative transport possibilities for the lease car trips. This study limited itself to five opportunities for changing travel need satisfactions[43]: Carpooling, using the train, using the bicycle, encouraging employees to work at the closets Capgemini office, and using a shared car. By setting limits to the allowable distance travelable by foot, bicycle, and car, each lease car trips was analysed in order to assess whether the travel need could have been satisfied differently. Studying the opportunities in isolation revealed that taking the train or the bicycle during the whole day will result in the largest trip reductions for Capgemini. Up to 17.7% of the lease car trips could have also been performed using the train (under the rough scenario). By using the train more often, CO_2 emission can be reduced. However the travel expenses increase when using the train. The bicycle also showed promise in substituting the lease car with 15.8% of the lease car trips that have the potential to be performable by bicycle (under the rough scenario). By taking the bicycle, both financial and environmental benefits can be achieved. Promoting bicycle usage can also result in employee health benefits. Carpooling is only interesting when combined with other alternative travel opportunities. The potential of using shared cars more often is small. Because it is questioned whether employees often have a choice at which Capgemini location they can work, no hard conclusions are made about this travel opportunity. More research is required. Combining different travel need satisfaction opportunities can result in a reduction of up to 17.2% of all lease car trips (realistic scenario). This trip reduction is mostly achieved by taking the bicycle and train more often. The big winners for alternative transport opportunities are therefore the bicycle and the train.

2.a. What are the expected benefits of the business transport improvements?
By combining different travel need satisfaction opportunities, financial and environmental benefits can be achieved. When financial benefits are pursued, 48,336 euro cost reduction per year is achievable, which is below the set threshold of 50,000 euro cost reduction per year. Therefore, no significant financial benefits can be achieved by changing the way travel needs are satisfied. When environmental benefits are pursued, the CO_2 emission can be reduced by 660,075 kg (7.93%) per year, a significant reduction. However, the reduction of CO_2 comes with a price tag of € 378,298 per year due to the increase in train travel costs. Thus, for every euro spent, the CO2 emission can be reduced by 1.74 kg.

[43] These opportunities were chosen in collaboration with the Director Facilities at Capgemini. The opportunities were chosen because it was expected that these opportunities would result in the biggest wins.

2.b. What are the tradeoffs of the business transport improvements?
Changing the way travel needs are satisfied can result in increased travel times, vulnerability to external forces, and a reduction in travel flexibility. It might also convince employees to change jobs. It is recommended to assess whether the benefits outweigh the negative effects on a per case basis.

This study did not reveal any significant benefits for Capgemini by switching from offering lease cars to offering mobility. However, this study did reveal the beneficial effects of promoting train and bicycle usage when possible. Capgemini might be better off to continue to offer lease cars to its employees as the baseline, and then promote usage of bicycle and train for its environmental and health benefits. The senior management of Capgemini do not have to be convinced to completely change the mobility policy. Small tweaks in the mobility policy (increasing the promotion of train and bicycle usage, and registering and encouraging carpooling) might be enough to reap the beneficial effects of changing the way travel needs are satisfied.

Companies with a lease car fleet usually register the business related travels of their employees for billing purposes. This data can also be used to discover the opportunities and expected benefits of changing the company policy (focussing more on offering mobility and less on providing cars). In this study the registered lease car trips of Capgemini were used. The same analysis can also be applied to other companies. Little data actually has to be gathered in order to perform the analyses. The for billing purposes collected lease car data is used in combination with a few other publicly available datasets. Using these datasets, the potential benefits by switching from providing cars to providing mobility can be quantified. Regardless whether offering mobility is an option or not, valuable information about employee travel patterns is gained from analysing the billing data, as was also shown in this study.

7.2 Discussions

A number of observations regarding the methodology and results of this study (that were not discussed in the previous chapters) are discussed in this section. Four topics are discussed: The limitations of the used lease car trip dataset are discussed in order to clarify in what way irregularities in the dataset affected this study. The limitations of the performed analyses are discussed to clarify what information can and cannot be gathered from the analyses results. The path dependency of changing or not changing the mobility policy is discussed in order to explore how today's decisions affect tomorrow's decision room. Finally, it is discussed how the analyses in this study could be abused by both employers and employees.

Limitations of used lease car trip dataset
A number of database correcting trips are contained in the registered business trip dataset. These corrections undo mismatches between mileage and actual travelled kilometres. Thus, not all business trips performed from January first 2015 up until the 31th of August are correctly represented in the dataset. However, only a small number of corrections (73) are found in the dataset, thus the resulting error in the dataset is expected to be small.

Related to these corrections in the dataset are expected human errors. Employees need to register their trip as either private or business related. Some business trips observed in the animation (e.g. trips on the Frisian Islands, or in Greece during holiday season) indicate that employees might sometimes erroneously register private trips as business trips. The magnitude of these incorrect registrations are hard to estimate using the provided dataset. Trips occurring during the holiday season in Greece are probably incorrectly registered as business trips. However, it is impossible to distinguish private trips from from business trips when an employee performs private travels (but registers as business) in the Netherlands during business hours on a work day. Nevertheless, it is expected that these erroneous private trips will not account for a large percentage of the registered trip, because the travel patterns as analysed in chapter 3 and 4 did not give rise to suspect structural human errors.

The dataset contains all trips beginning in January 2015 up until August 2015. Thus, a number of months in 2015 are not taken into account for the performed analyses. This means seasonal effects might have influenced the results. However, the Director Facilities, who oversees the mobility facilitation of Capgemini employees, stated that seasonality effects the number of lease car trips only little (Knol, 2015).

Limitations of performed analyses

An animation was made to visualize the travel patterns of the lease cars. This visualisation depicted the routes the lease cars travel as the crow flies because the exact route the cars travel is not saved. By visualising the car routes as the crow flies, routes that are often travelled by Capgemini cars are harder to identify.

In order to better visualize the parking locations of the Capgemini cars, parked cars were allocated to a number of fixed parking locations in the Netherlands (and abroad). The resulting figures (e.g. figure 22) show clear parking hotspots. However, due to parking aggregation, some cars that are parked at the outskirt of a city are allocated to a different city. However, these erroneous allocated cars will not affect the visualisation of the parking hotspots much, thus aggregation is deemed acceptable.

The analyses of the employee travel patterns cannot uncover the carpools and car shares already occurring. Hypothetically there are already numerous employees sharing cars or carpooling at Capgemini. The trip registration system does not register these car shares/carpools because it does not measure the number of employees in a lease car. However, based on the researcher's experiences and informal conversations with the Capgemini employees, it is deemed highly unlikely that employees are carpooling or car sharing often at the moment. This hypothesis is supported by the Director Facilities at Capgemini. Nevertheless, it is recommended that in future research, the number of carpools and car shares are measured.

When looking for Carpool opportunities, only employees with similar origins and destinations were taken into account. This neglects possible carpools of employees who could have been picked up at an intermediate location on the route from origin to destination. This analyses was not performable using the business trip billing dataset because, as discussed before, the exact route travelled by each lease car was not available. Therefore the number of potential carpools might be larger then presented in this thesis.

Another carpool possibility not taken into account is lease car employees carpooling with private car employees. Because no data about the business trips of private car employees is available (to this study), these carpool possibilities were not analysed.

An important part of the public transport network was neglected: the bus network. Possible trips performable by bus were not analysed because this requires information about the bus network which is not available to this study. However, it is expected that analysing the trips performable by bus would not result in new insights. Two possibilities exists for taking the bus: taking the bus for short length trips, and taking the bus for intercity trips. Bus trips over short distances are often also performable by bicycle (trip < 12.5 km). This makes the bus only a preferred travel method over taking the bicycle when the weather does not allow for a bike ride[44]. Alternatively, a bus can be used to travel between cities when a connection by train is impossible. However, the Netherlands has a large number of decentralised train stations (appendix H), thus it is expected that only a few trips not performable by train, would be performable by bus.

For the bicycle opportunities, the E-bike was not studied separately. It might be possible that employees are willing to travel further than 12.5 kilometres single journey when an E-bike is used instead of a regular bike.

A number of hybrid trip solutions were not taken into account. For example, a trip origin and destination has to be located within 1.5 kilometre of a train station to be considered as a possible trip performable by train. However, let's assume an employee can take the bike to a train station. Now the origin can be located within a 12.5 kilometre radius of the nearest train station to be considered as performable by train (and bike). Numerous other combinations of walking, cycling, carpooling and taking the train are conceivable. However, these hybrid trips are deemed to fall outside of the scope of this study. Further research about hybrid trip opportunities is recommended.

This study assumed that when an employee travels using a different method of transportation (carpool, train, bike, etc.) his travel needs would not change. This does not necessarily has to be the case. An employee travel-

[44] Taking the bus causes more CO_2 emission due to the petrol engine and is expected to be more expensive due to the ticket price.

ling by carpool can chose to plan a meeting the next day when he again has his lease car available to him. Similarly, an employee travelling by train can request that his co-workers come to a meeting point near a train station instead of him travelling to a meeting point with bad public transport access. Thus, more opportunities for travel needs satisfaction using alternative transport methods might be feasible.

The “getting back home” scenario assumed that people need to get back home. This does not necessary has to be the case. When commuting times exceed 1.5 hour single journey, a Capgemini employee is eligible for an overnight stay at a hotel. When this is the case, the employee does not have to return to the location from which he started to travel in the morning[45]. However, most trips by Capgemini lease cars are for commuting (see chapter 3 & 4), thus the assumption that employees need to return to their home seems reasonably valid.

In order to estimate the benefits for Capgemini per year for their entire car fleet, 8 months of trip data containing 1,729 out of the 3,000 was analysed. This data was then extrapolated to 12 months and 3,000 cars. This extrapolation is only valid when no significant seasonal effects occur during the year and when the sample (1,729 cars) represents the total population (3,000) accurately. It might be useful to repeat the research when every Capgemini lease car is outfitted with an onboard computer.

Something to consider: the average fuel economy and carbon dioxide emission has been going down since 1975[46] (Schipper, 2006; Alson, Hula, & Bunker, 2014; Tietge & Mock, 2014). Compared to 1975, fuel efficiency has roughly doubled and carbon dioxide emission has halved(Alson, Hula, & Bunker, 2014). Capgemini reduces its expenses by 0.109 euro per lease car kilometre reduction. Roughly half of that cost reduction is due to the decrease in fuel usage (Knol, 2015). Fuel economy can be greatly improved with the introduction of hybrids, and electric vehicles (Loiseau, 2013). Thus financial benefits might be achievable by increasing the number of electric vehicles in the lease fleet. Note that this reduction is achievable, without requiring any change in employee travel behaviour. Promoting employees to lease fuel efficient or fully electric cars might therefore be an opportunity for “changing” the way travel needs are satisfied that results in a financial benefit with little tradeoffs for Capgemini. Further research into the expected benefits and tradeoffs of promoting fuel efficient or fully electric lease car usage for Capgemini is recommended[47].

In the European union, a target is set to reach an average carbon dioxide emission of 95 grams per kilometre in 2020 for new passenger cars (Tietge & Mock, 2014). Lease cars are in general new cars, thus this reduction in average carbon dioxide emission for new passenger cars will automatically affect the average carbon dioxide emission of the Capgemini lease cars. If the European target is reached, then this can result in a reduction in the carbon dioxide emission for Capgemini without needing any intrusive measures.

Path dependency

Changing the way employee travel needs are satisfied can results in some undesirable consequences in the future. By promoting the usage of public transport, employees will use their own lease car less. Taking the train will result in an increase in the travel expenses for Capgemini. On the other hand, it is expected that taking the train will result in a beneficial reduction of CO_2 emission. However, due to the introduction of the fully electric car, it is conceivable that the CO_2 emission of driving a car is actually lower than (or at least comparable to) the CO_2 emission when taking the train. In this case, the Capgemini policy change caused employees to leave their cars and more often take the train while taking the train only costs money and does not significantly change the CO_2 emission. Getting the people out of the trains and back into their cars will then again require effort.

Not changing the way employee travel needs are satisfied can results in some undesirable consequences in the future. Although trains are more expensive than lease cars, their CO_2 is lower, and it is expected that within reasonable time, all Dutch train will completely operate on green power (Nu.nl, 2014). With increasing restrictions on the amount of CO_2 that companies can exhaust, taking advantage of the train might be necessary. Projects like the bicycle highway and the introduction of the electric bicycle will also improve range of using the

[45] This goes for both the trip from home to the hotel as well as the trip from the hotel back home.
[46] When looking at multiyear trends
[47] There is no consensus about the depreciation of electric cars, thus the savings in fuel might not weigh up to the change in lease car depreciation.

bicycle for business travels. Thus bicycles might also become more and more appealing. Moreover the lease car contracts of Capgemini are often closed for a period of four years. When employees are not convinced to quit using their lease car early on, Capgemini might be stuck with a large lease car fleet while most employees are travelling using alternative transport modes (because of CO_2 emission restriction).

Abusing the system
The business trip billing data was used in this study to analyse the travel patterns and assess whether facilitating mobility instead of offering lease cars is an option for Capgmini. However, using the same dataset and roughly the same analyses techniques, other insights can also be gained. For example, business trip origins and destinations for commuting trips (trips from a business location to a private location) are saved. These postcodes or geographical locations can possibly be linked to the Google Maps database[48]. In this way, the type of location visit (residence, business location, recreation establishment, etc.) can be identified. This information can then be abused: An employee who often visits the hospital after work might have health problems. Something to consider when a division needs to let a number of people go. Visits to a brothel after work could potentially show up in the commuting trip data. Capgemini perhaps does not wish to be associated with whoremongers, resulting in the termination of the employee’s contract.

Both the travel distance and the travel duration can be extracted from the dataset. Employees with an average travelling speed greater than 130 kilometres per hour are most likely violating the speed laws. Insurances sometimes do not cover accidents when the driver is breaking the speed limit. Thus, employees breaking the speed limit results in a financial risk for Capgemini. Therefore it might be interesting for Capgemini to take away the lease car from employees who structurally drive faster than the speed limit.

More generally, visits that start at the employees house and end at a location without any known business contacts of Capgemini (e.g. the local football club) are easy to identify as private instead of business travels when the postcodes or coordinates are linked to the Google Maps database. Thus the lease car trip database can also be used to detect incorrectly registered lease car trips.

Vice versa, when no connection is made to the Google Maps database (or a similar database) the employee can easily abuse the current system. When an employee registers his private trips performed on workdays during (or roughly before/after) work hours as business trips, Capgemini has a hard time detecting these incorrectly registered trips.

7.3 RECOMMENDATIONS

Some recommendations are given for further research and business developments. Recommendations are given specifically for Capgemini, recommendations are given for assessing the potential of switching from offering lease cars to offering mobility, and recommendations are given for analyzing businesses using the lease car billing data.

Recommendations for Capgemini
Environmental and health benefits are achievable by promoting the usage of trains and bicycles instead of lease cars. As a next step in changing the Capgemini mobility policy, a study about the willingness of employees to change their behaviour is recommended. This study should attempt to quantify what incentives (financial or other incentives) are required to change employee travel behaviour. This data should then be used to explore the opportunities and expected benefits of intensifying train and bicycle usage further.

This study showed that by changing travel need satisfaction, significant CO_2 emission reductions can be achieved. It is recommended that Capgemini now uses this information to decide what CO_2 emission reductions are desirable and what the acceptable increases in travel expenses are in order to achieve these CO_2 emission reductions.

[48] Linking to this database will costs some time and this database can only be accessed a limited number of times for free.

Recommendations for analyzing the potential to switch to providing mobility
Chapter 6 discussed what factors influence whether offering mobility or offering lease cars is preferred as a company. Chapter 6 also discussed how the business trip billing data can be used to analyse the employee travel patterns at other companies. For further research it is recommended that different travel scenarios are considered when quantifying the potential of offering mobility instead of cars. Travel possibilities like commercial shared car services, the public transport bicycle, the bus, self driving cars, and new combinations of all previously discussed travel opportunities should be taken into account. By taking more travel opportunities into account, the non-lease car mobility possibilities will become clearer.

Recommendations for analysing business trip billing data
In order to professionalize the business trip billing data analyses, a logical next step would be to develop a tool that uses the registered trip data from a company and the additional datasets about public transport networks in order to map the travel behaviour of employees. This tool would automatically produce the necessary graphs and figures[49] to answer the client's mobility questions. The tool could then be used facilitate in setting the employee mobility strategy of a firm.

[49] Questions graphs and figures similar to the ones presented in this thesis

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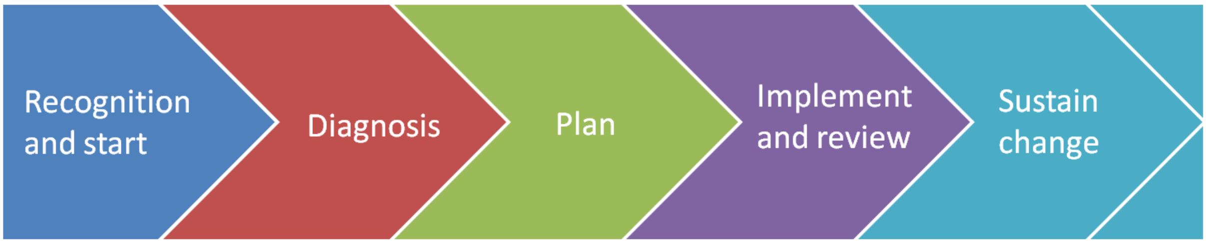
APPENDIX A: CHANGE MANAGEMENT

Why change management?

Change management has been discussed in numerous publications (Raineri, 2011). Initiating change in a company can be done following various procedures. At the extreme ends of the spectrum one can either completely follow intuition or completely follow a formalised, documented and structured procedure. Managers implementing change without structuring the implementation are at risk to relapse in a hit-or-miss change management system, implementing the most visible bits while neglecting the larger scope of the intended change (Brynjolfsson et al., 2012). Near misses in implementing change in a company can leave a firm worse off than if it had never attempted the change (Brynjolfsson et al., 2012). The use of structured change management has a considerable impact on the success of the change program goals and deadlines (Raineri, 2011). A structured approach to initiating change in a company is therefore recommended.

Conceptualizing change management

Effective change management depends on the ability to recognize the complements in technology, practice, and strategy. "Managers must plan a strategy that coordinates the interactions among all the components of a business system" (Brynjolfsson et al., 2012, p. 1). A framework for change management is given by Hayes (2014). In this framework, 5 steps for achieving change in a business context are defined (figure 3). The 5 steps of Hayes (2014) are discussed below.



APPENDIX FIGURE 1 MODEL CONCEPTUALIZING THE MANAGEMENT OF CHANGE AS A PURPOSEFUL CONSTRUCTED PROCESS (BASED ON HAYES 2014)

The change management starts with the recognition that there exists a discrepancy between the current situation and the desired situation. External events (e.g. market crash, change in material availability, new disruptive technology) or internal events (e.g. change in staffing, fusion or division of company) can create a reality where change is needed. During the recognition stage, a number of actions are performed. The need for change in the company should be transformed in a desire of managers to pursue the change. Without this desire, no driving force facilitates the change. Wide participation in the change process is often advised in both management books and scholarly literature (Lewis et al., 2006). A shared perception of the need to change is created by this process. The people who get involved in the change management affect the chance of success. Change does not necessarily have to be led by a manger. However, the chance of success of the change process is increased when employees perceive that their leaders are actively involved and committed to the change process (Raineri, 2011). Thus managerial support is preferred.

With a shared perception of the need to change and an active change agent (manager or otherwise) committed to the change, the diagnose stage of the change management can begin. During the diagnose stage, the phenomenon that triggered the need for change is assessed and possible opportunities for change are explored. Analysis of the organizational system and its environment, identification of the change needs and the development of a new organizational vision are performed in this stage (Raineri, 2011). The need for change is spread through the company during this phase. The analysis of the problem should prove that the current situation is undesirable for the stakeholders. A new organizational vision is designed that present a brighter future that rallies the stakeholders. The diagnosing stage is "finished" when an idea is formed what change is desired.

After the diagnose stage, the planning stage begins. The planning stage describes how the desired change is achieved. Some of a company's key resources can only be spent once. The planning stage determines how much and when key resources are spent to achieve the desired change. When a clear change goal is set, the planning stage can give a structured plan of approach for achieving the goal. However, sometimes the desired goal is less clear. The planning stage is then an iterative process (along with the diagnose stage). The change goal and plan of approach are adjusted each iteration.

When the plan of approach is clear, the change can be initiated. During the implement and review stage, a shift occurs from planning to actions. During the change implementations, management deploys the change plan. Careful attention has to be paid to the effects of the implemented plan. The progress is monitored and the change is reviewed. Continuation of communication with the stakeholders will hopefully produce the feedback necessary to keep the change on track. During the implementation and review stage, keeping the stakeholders invested in the change process is key. Acceptance and adaptation of change improves when good effort is put into issue selling (Dutton et al., 2001). Proper compensation and incentive systems also facilitates change adaptation (Kanter, 2001). The implementation and review stage is finished when the intended new situation is achieved.

Achieving the desired situation is one thing, sustaining it, is a different story altogether. After a successful change implementation, the change should be sustained as long as it is useful. A change can be classified as sustainable when the new ways of working and improved outcomes become the norm in the firm. The support system that facilitates business of a firm should backup the new ways of working. After a successful change in a firm, the firm can still revert back to its old ways of doing business. After the successful change implementation, the change agents shifts their attention to new projects. The driving force behind the change then disappears. This release of pressure to change can result in a regression of the firm into situation pre-change. This is especially true when the support system that facilitates the business of a firm mostly supports doing business in the "old ways". By paying attention to the evolution of the firm after the change is successfully implemented, sustainable change is easier achieved. Continuation of communication with the stakeholder about the change, its effects on the firm, and the achievements of the firm due to the change can help achieve sustainable change.

The above conceptualization of change management implies a linear process. However, change management is almost never linear. Recognition, diagnose, planning and implementing change are processes that often occur simultaneously, an repeatedly. Steering change in the right direction is an iteration of the whole process on itself. This should be considered when change is needed or already occurring in a firm.

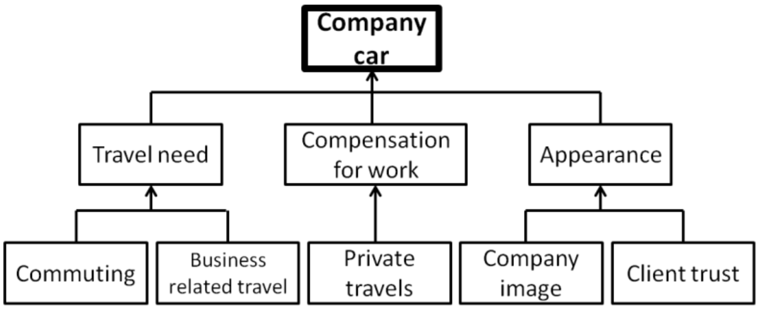
APPENDIX B: CASE STUDY JUSTIFICATION

CASE STUDY

Because employee travel data is used from only one company and the focus of the research is specifically on this company, the proposed research can be classified as a case study. Baxter and Jack (2008) state that case studies give researchers the opportunity to explore a phenomenon in context. For the proposed research, the travel behaviour of the Capgemini employees are explored in order to find improvement opportunities. A case study is used to answer "how" and "why" questions and the researcher has no influence on the case itself (Yin, 2003). This fits with research question 2 which specifically asks "how" something can be done. Moreover, the historical employee travel data cannot be retrospectively influenced in anyway, thus the researcher has no influence on those involved in the study. A number of different case study types are classified in literature. Baxter and Jack (2008) present 7 case study types in their paper. Following the classification of Baxter and Jack (2008), the proposed research fits the instrumental case study. According to Baxter and Jack (2008), an instrumental case study provides insight into an issue. The case is of secondary interest; it has a supportive role, facilitating the understanding of something else. This corresponds to the proposed research approach. The Capgemini travel data is primarily used to develop a method to explore business travel improvement opportunities. Ideally, this method is then applicable to other employee travel datasets.

APPENDIX C: COMPANY CAR FUNCTIONALITY

In the research objective and questions section it was assumed that the company car's only function is to transport employees. This assumption might be too simplistic. Appendix figure 2 gives an overview of the possible functionality of the company car, including the non-transport related functions.



APPENDIX FIGURE 2 FUNCTIONALITY OF COMPANY CAR

By providing employees with a car, their effort required to commute and travel for business is lowered. Beside facilitating the travel needs of its users, the company car can fulfil alternative functions. The company car provides a benefit to the employee because the employee can use the car for both business and personal trips (Cohen-Blankshtain, 2008). Providing a company car is therefore a form of employee compensation. For an employer, the promise of a company car can be a method to attract motivated personnel (De Witte & Macharis, 2010). The company car can also affect the prestige and status of the employee (Gilbert & Morris, 1995; Cohen-Blankshtain, 2008). Driving a high cost car can affect the attractiveness of an employee (Dunn & Searle, 2010). A professional employee driving a professional (read: expensive) car can change or confirm the company image perception of a customer. An expensive business car can also backfire catastrophically as was proven in the case of the former CEO of housing corporation Rochdale (Nu.nl, 2014). When the firm policy about company cars is changed, the change in compensation of work and appearance for the employees should also be taken into account.

APPENDIX D: GETTING EMPLOYEES OUT OF THEIR CAR

Kingham, Dickinson, and Copsey (2001) researched what factors influence the employee commute modal choice of two companies in the UK. Their survey revealed that the employees are genuine willing to move out of the car for the journey to work. However, still only a limited number of employees actually travelled by a different mode then automobile. Kingham, Dickinson, and Copsey (2001) found a number of action that an employer can take to motivate employees to either change transport mode, use their company car more efficiently, or decrease their travel need:

Working at home: One of the main barriers for leaving the company car at home was the perception that no viable alternative existed. The car is sometimes taken even when it is not objectively the best transport mode (Innocenti, Lattarulo, & Pazienza, 2013). One possibility for leaving the company car at home, is simply not leaving the home in the first place. By promoting working at home (when possible, and not affecting productivity) the company car usage can be decreased.

Cycling facilities: Similarly, employees often perceive cycling to work as an unfeasible alternative to using the car. Offering cycling facilities (bicycle racks) at the firm was deemed to improve the willingness of employees to cycle to work. One important limiting factor to the usage of the bicycle was the distance between home and work. A number of employees in the Kingham, Dickinson, and Copsey (2001) study were willing to bicycle to work, but were unable due to the large distance between work and home. A more rigorously policy employers could implement is promoting employees to move closer to their work. This will reduce the commute distance travelled by car and opens up the possibility to commute by bicycle.

Public transport: Informing employees about the travel alternatives using public transport was also deemed by Kingham, Dickinson, and Copsey (2001) to positively influence the public transport usage of the employees. Other factors that improved the willingness of employees to use public transport (e.g. frequency, reliability, convenient drop off sites and better connections) were outside of the employers sphere of influence.

Car sharing facilitation: Introducing a car sharing program seemed a very achievable policy employers can implement to reduce the company car usage. Employees are attracted to the idea of reducing their car use for commuting while still travelling by car (Kingham, Dickinson, & Copsey, 2001). Employees indicated that a system that facilitates the car sharing would encourage them to reduce their car usage. However, people view car sharing as unreliable. A fear exists that the due to circumstances the shared ride won't be available when they need it, resulting in extreme travel delays. A possibility to reduce this fear is to introduce a backup taxi service in cases of force majeure.

Financial incentives: Employees are more willing to change to transport mode (either car sharing, cycling, or public transport) when financial incentives are given. The study of Kingham, Dickinson, and Copsey (2001) showed that commuting is also still very much a financial consideration. Beside simply offering money in exchange for not using the company car, negative financial incentives are also possible. Forcing employees to help pay their company car fuel expenses, or restricting and/or charging employees for car parking can increase the willingness of employees to use their cars less.

Assuming that the proposed research uncovers business travel improvement opportunities, then the above described methods can help in implementing the new business travel policy. The above described methods would typically be explored in the planning stage of the change management.

APPENDIX E: EXTENDED DATA QUALITY ANALYSES

APPROACH

The registered trip data does not necessarily accurately represent the actual travels performed. In order to perform the study on realistic data, a number of quality checks are performed on the entire dataset:

- Checks on empty variables
- Checks on trips with negative travel time or distance
- Checks on trips with zero travel time or distance
- Checks on trips with very slow or fast average travel speeds
- Checks on very short or long trips (in time and space)

Based on these checks, a number of trips are flagged as unrealistic or unusable for further analyses.

EMPTY VARIABLES

Trips with missing variables might not be usable for further analyses. When important information like timing and origin/destination of the trip are unknown, very little knowledge can be gained from analysing this trip further. Therefore, the dataset is checked for empty variables.

Most variables contain an entry for every trip. The following variables did contain empty cells[50]: Departure address (1069 missing; 0.19% of total number of trips), Departure postcode (4000; 0.74%), Departure city (1070; 0.20%), Departure country (1051; 0.19%), Arrival address (3817; 0.70%), Arrival postcode (6785; 1.25%), Arrival city (3820; 0.70%), Arrival country (3798; 0.70%), and End mileage (48; 0.01%). Notice that the missing data is mostly related to the location of the car. A number of possible reasons exist for the lack of location data. The location data is registered using GPS data. It is possible that the GPS receiver was unable to calculate its location at the time of departure or arrival. Alternatively, a number of trips (73; 0.01%) that did not contain location data, were corrections in the system for either a trip not registered by the automatic system, or a correction on the travelled kilometres due to a mismatch between mileage and actual travelled kilometres. Of all trips, 1051 (0.19%) do not contain any data on the location of departure, and 3798 (0.70%) do not contain any data on the destination. Roughly half of all these trips also have no distance travelled. Possibly, the car is started and a business travel is initiated (by pressing the button), but the trip is cancelled shortly thereafter. This will result in zero kilometres travelled. When performed in a very short time span, the onboard computer then has too little time to calculate its location. This study focuses on moving cars. Thus location data is deemed necessary. Therefore, trips that contain no location data are excluded from the analyses in the following chapters. Note that relatively less than 1.5% of the trips contained empty variables. Thus 98.5% of the dataset is suitable for further analyses based on the missing data criteria.

For 48 (0.01%) trips, the end mileage of the trip is unknown. However, the registered distance travelled is known. Therefore, this data is redundant.

NEGATIVE TIME/DISTANCE TRAVELLED

Trip data that conflicts with the laws of reality are most likely incorrect registrations of trips. These trips need to be filtered out before further analyses are performed. The car fleet of Capgemini does not contain any custom DeLorean's, thus negative travel time is impossible (Back to the future, 1985). Negative travel distance is also not possible anymore by driving backwards since the introduction of electronic odometers in the 90's (Ramakrishnan, 2013). Therefore a check is performed on trips with negative distance or time travelled. It is assumed that these trips do not represent actual travels by car. Eleven trips are found that state negative distance travelled. These trips are mostly corrections due to a mismatch between mileage and actual travelled kilometres. Seventeen trips state negative travel times. Moreover, these trips also report a positive travelled distance. It is

[50] Number of trips that contained a specific missing variable is given in between the brackets.

unclear what the reason is for these weird measurements. Most likely they are also correction to the system. All negative travel distances and travel times are removed from the dataset for the analyses in the following chapters.

ZERO TIME/DISTANCE TRAVELLED

Similar to the negative travel time/distance trips, trips with zero travel time/distance are also either unrealistic (in the case of zero travel time/distance in combination with positive travel distance/time) or useless (in the case of both zero travel time and distance). Of the total dataset, 3559 trips (0.66%) registered zero travel time. All trips with zero travel time are deemed unrealistic and therefore removed from the dataset in the coming chapters. For 16881 (3.1% of total data set) trips, zero distance travelled is detected. All 16881 trips are most likely the result of mistakes by either the system or the employee, which results in a trip entry without any actual travel. These trips are omitted from the dataset because no knowledge can be gathered by incorporating them in the datasets.

AVERAGE VELOCITY

Another way erroneous trips can be identified is by looking at the average travel speed. The average velocity of a trip can be calculated using the distance travelled and the registered travel time. Two extremes are possible, either the car is travelling way too slow or way too fast. After filtering for trips with negative or zero travel time/distance, 4300 trips (0.79%) have an average travel speeds lower than 5 km/hour. Out of these 4300 trips, 4105 trips (0.76%) travelled less than 1 km. These trips are peculiar. Travelling over those distances, walking would be a viable alternative to using the car, thus taking the car might not have been worth the effort. However, it is not unthinkable that employees actually used the car to travel 1 km with an average velocity of 5 km/hour or less. For example, the employee could press the button to register a business travel, and then finish a call first, before driving 1 km to the destination. This would make the average travel speed slower than 5 km/hour. Because it is feasible to travel with an average velocity slower than 5 km/hour, these trips are not removed from the dataset. However these trips will be analysed further in the coming chapters.

At the other end of the spectrum, trips with extremely fast average travel speeds are found. The physical limitations of a car and its environment guarantee a certain speed limit. Crossing this limit is a good indication that a trip is erroneous. After filtering for trips with negative or zero time and distance, 239 trips (0.04%) are found that have an average travel speed faster than 150 km/hour. Twenty of those trips are corrections of the system, and therefore do not represent actual travels. Of the 239 extremely fast trips (0.04%), 207 travelled only a very small distance (<2 km). It is unlikely that these travels actually occurred because it is very hard to reach speeds faster than 150 km/hour over a distance of 2 km (assuming the cars are parked at the start of the measurements). If the car is not travelling on a highway, speeds over 150 km/hour are even harder to obtain. All 239 trips (0.04%) that measured average travel speeds larger than 150 km/hour are removed from the dataset because they are unlikely to have occurred. If one of these trips did occur, then the employee is most likely in violation of multiple traffic laws. Erroneously deleting tens of trips due to a high average travel speed will not affect the conclusions of this study because a large number of trips (542 651) are analysed.

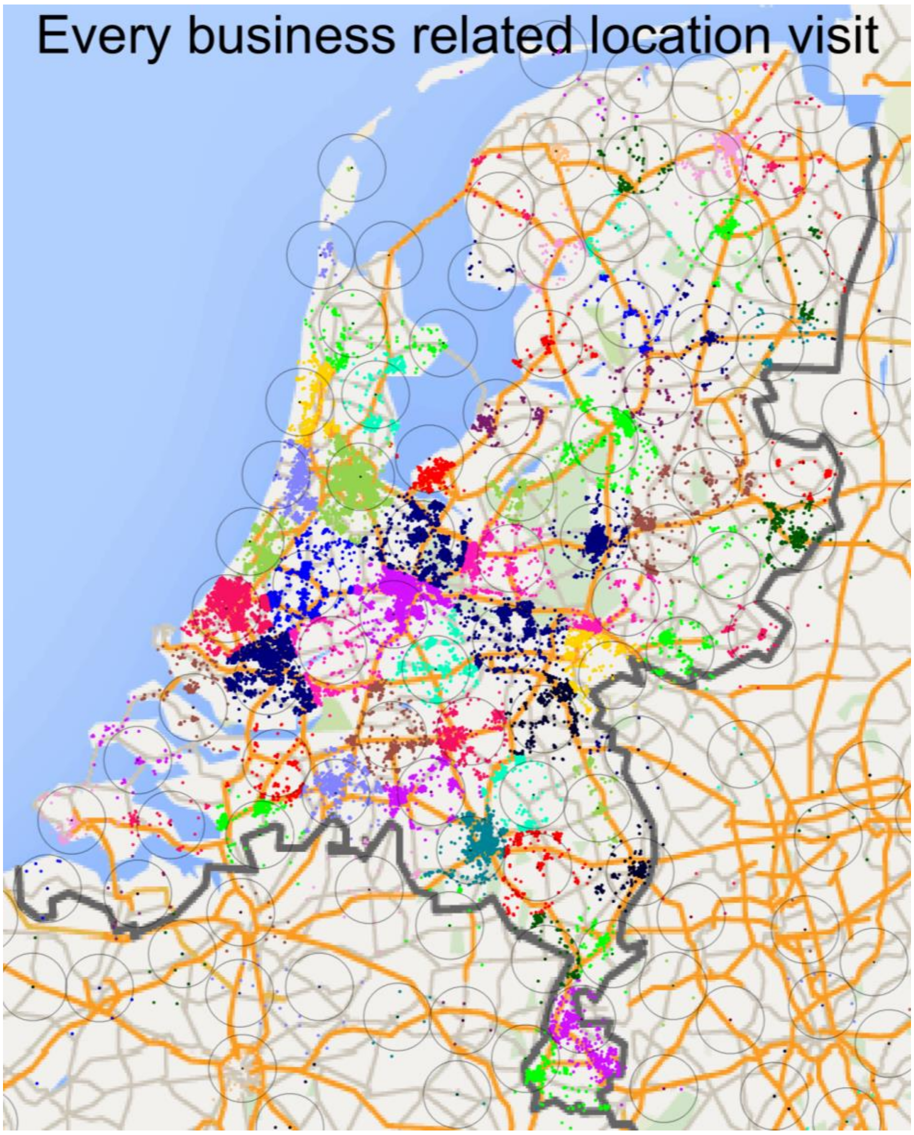
VERY SHORT OR LONG TRIPS

The last check made is related to very short or long trips; both time and distance wise. In the dataset there are 6135 (1.13%) trips that took less than a minute, and 12120 trips (2.23%) that travelled less than 300 metres (after removing the zero and negative travel time/distance). It is unclear whether these trips actually occurred or not. Due to GPS inaccuracy, starting the car, registering for a business trip, and then turning the car off again can result in the onboard computer registering a trip even though the car has not moved an inch. Whether or not this is the case for all these trips remains to be seen. Because there is no way to be sure these trips actually occurred or not, it is assumed that they are valid.

A check is performed on very long trips (+10 hours or + 900 km). Only three trips were found with travelled time or distance larger than this threshold. The average speed of these trips were within the expected margins for these lengths of trips. Therefore these trips are classified as realistic and left in the dataset.

On a side note: if it is assumed that trips with a length smaller than 300 meter are incorrectly registered, then this means Capgemini is paying for kilometres that in fact were not travelled. Added together, all trips shorted than 300 meter amount to 1607 km. Assuming a standard 0.19 euro per driven kilometre (Rijksoverheid, 2015), this means in eight months time, the Dutch branch of Capgemini has paid 305 euro too much tax free mobility allowance. This is negligible compared to the total lease car expense of Capgemini.

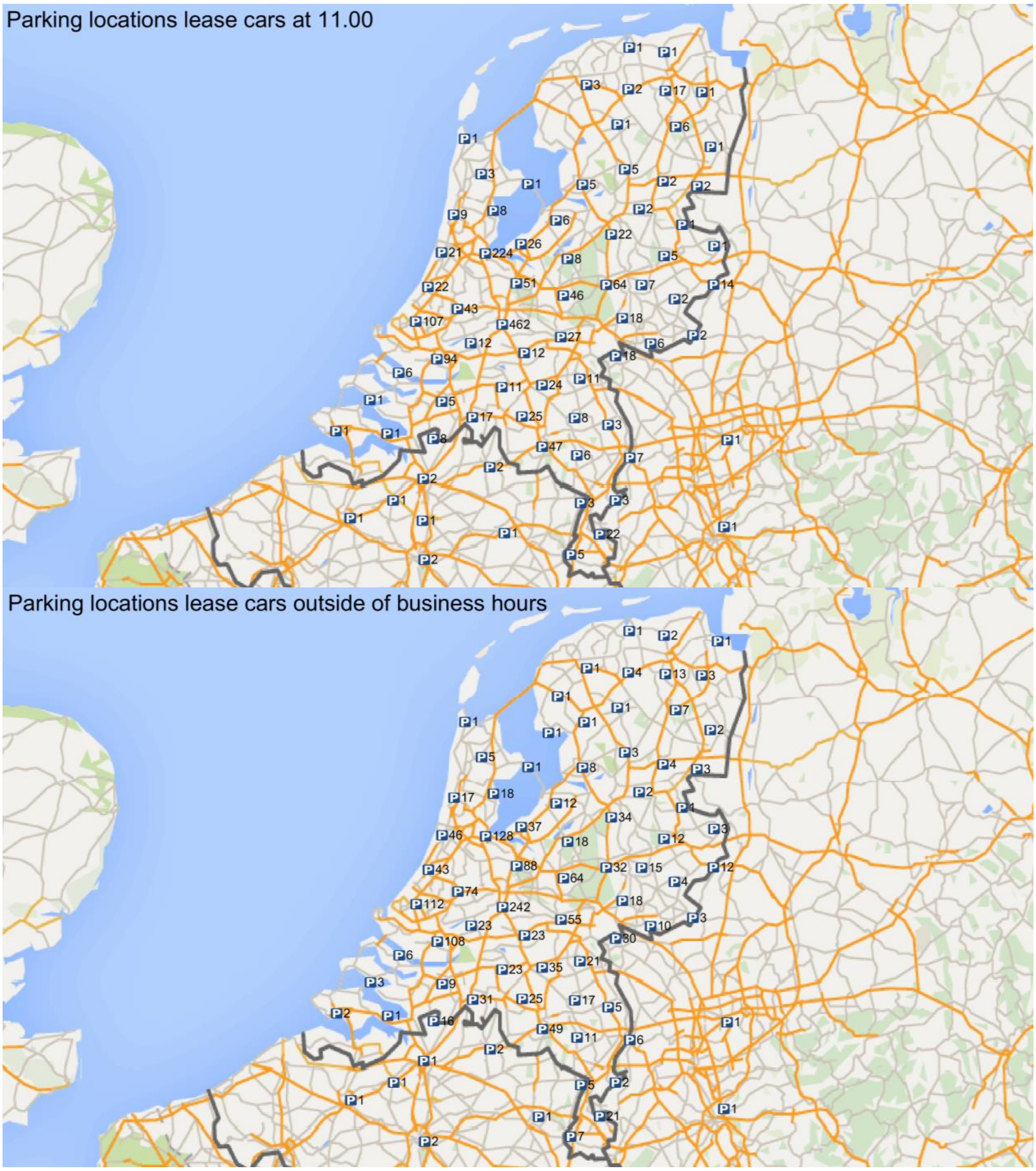
APPENDIX F: AGGREGATION OF ALL LOCATIONS VISITED



APPENDIX FIGURE 3 ALL DUTCH LOCATIONS VISITED, COLOR CODED BY THEIR SHARED AGGREGATED PARKING LOCATION

Every location visited by a lease car is aggregated to a aggregated parking location with a radius of 20 km. However, the aggregated parking locations with the 20 km radius overlap each other. Appendix figure 3 shows all locations visited by a lease car in the Netherlands. The points near each other with the same colour represent locations that are aggregated to the same aggregated parking location.

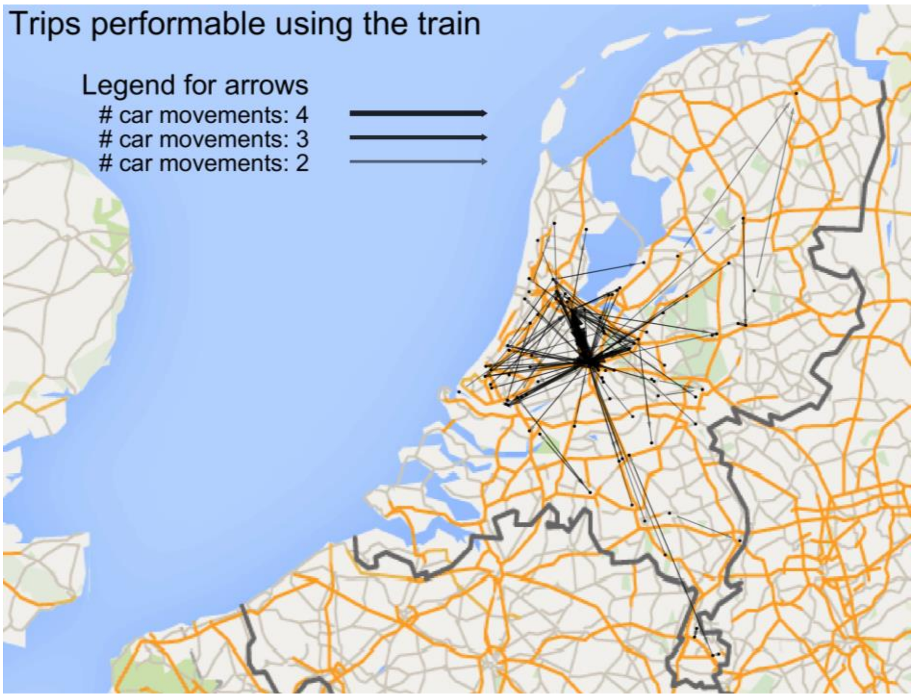
APPENDIX G: NUMBER OF CARS PARKED DURING AND OUTSIDE OF BUSINESS HOURS



APPENDIX FIGURE 4 MAPS DEPICTING THE NUMBER OF CARS PARKED DURING BUSINESS HOURS (11.00) AND OUTSIDE OF BUSINNESS HOURS (03.00)

APPENDIX H: TRAIN STATIONS IN THE NETHERLANDS AND FLUXES OF EMPLOYEES BETWEEN TRAIN STATIONS

APPENDIX FIGURE 5 ALL TRAIN STATIONS IN THE NETHERLANDS.



APPENDIX FIGURE 6 POSSIBLE TRIPS TO AND FRO THE DIFFERENT DUTCH TRAIN STATIONS ("ROUGH " SCENARIO). NUMBER OF TRAIN MOVEMENTS AVERAGED OVER NUMBER OF WORK DAYS.