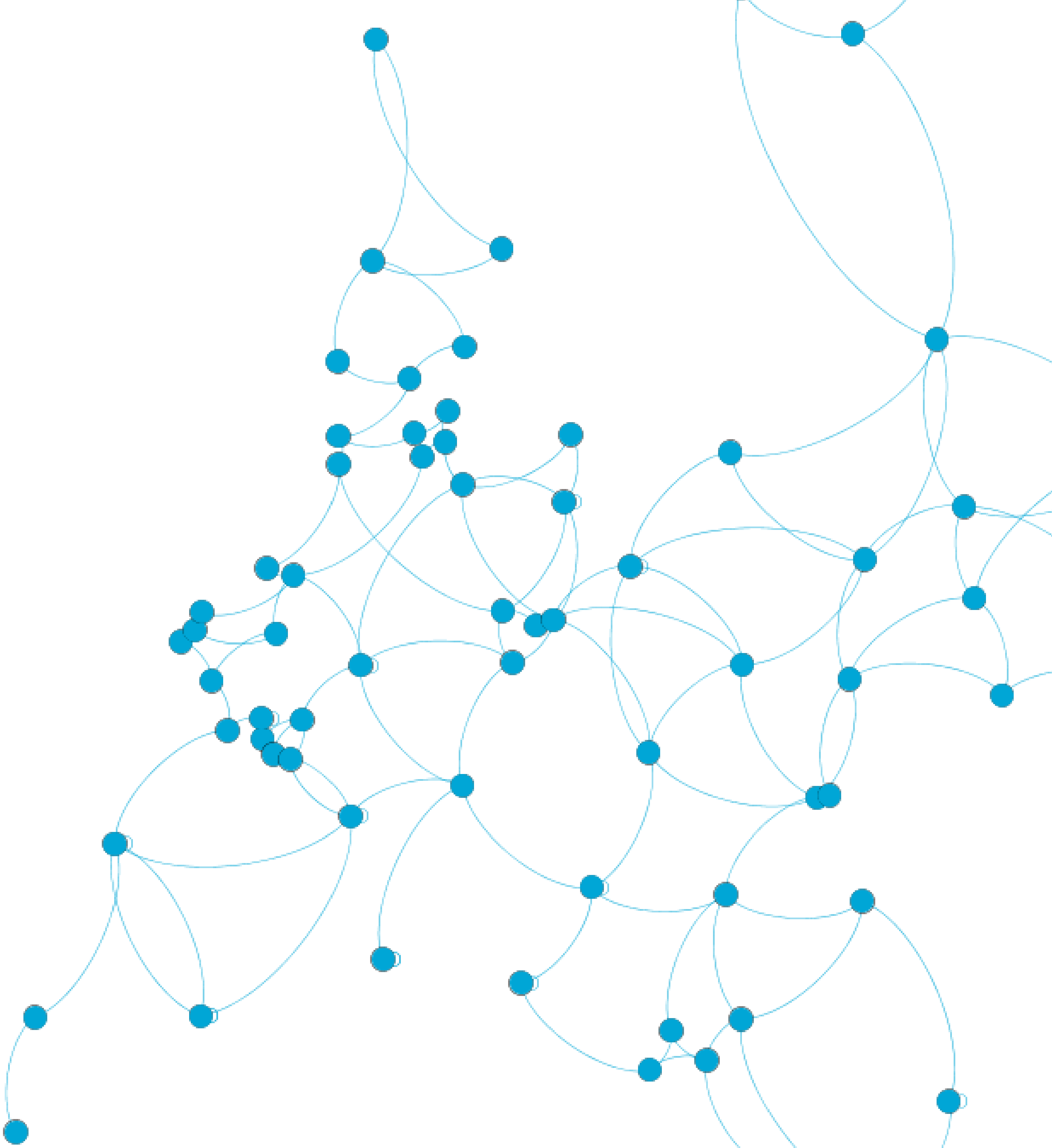


Empirical research on the distribution of hospitals in the Netherlands

Substitutability of hospital locations: the case of obstetrics care

Charlotte Giesbers

This page is intentionally left blank

Empirical research on the distribution of hospitals in the Netherlands

Substitutability of hospital locations: the case of obstetrics

---

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Complex Systems Engineering and Management**

Faculty of Technology, Policy and Management

by

Charlotte Giesbers

Student number: 4268172

To be defended in public on 27 May 2019

Graduation committee

Chairperson	: Prof. Dr. G. P. Van Wee, section Transport and Logistics
First Supervisor	: Dr. C. Maat, section OTB – Research for the Built Environment
Second Supervisor	: Dr. Ir. S. Van Cranenburgh, section Transport and Logistics

This page is intentionally left blank

Preface

Before you lies the report that contains my thesis research. This work serves as partial fulfilment of the requirements for the degree of Master of Science in Complex Systems Engineering and Management at the Delft University of Technology. The thesis is the result of a period of hard work in which I experienced several ups and downs. Writing a suitable proposal and then also actually conducting the research in a scientifically correct manner turned out to be a very challenging task. When reflecting on the process, I think I made several planning mistakes. Balancing time, effort and personal life proved to be difficult. Nevertheless, I can conclude I learned a lot on a scientific as well as a personal level. Needless to say, I could not have succeeded without the support of several people.

First and foremost, I would like to thank my graduation committee, Kees Maat, Sander van Cranenburgh, and Bert van Wee. Their enthusiasm about substitutability motivated me to pick this subject. As I regularly questioned my ability to conduct research on an unknown topic like this, their constructive feedback and recommendations were very much appreciated.

I would also like to thank some people from RIVM. Without being involved officially and without asking anything in return, these people shared their expert knowledge with me, for which I am very grateful. Henriette Giesbers has been very supportive throughout the process and also helped me with mapping my results. Geert Jan Kommer provided interesting comments and recommendations on how to shape the research process.

Another big thank you to all respondents and in particular the people that filled out the pilot survey. Without your opinion and helpful comments on the description and outlook of the survey, I would have not been able to successfully complete this thesis. A special thanks to the relatives and friends that shared the survey with their personal networks.

Last, but certainly not least, I would like to thank my family and friends. To start with my parents. I would like to thank them for always being available to provide the needed support. The month I spent at their place post-surgery may not have been the most productive, but it certainly helped me grow the motivation I needed to work hard and succeed. I also would like to thank my brother for the laughs at football. Furthermore, I would like to thank my boyfriend Redmer for always being there for me and calming me down in stressful situations. Without your rational point of view and the sometimes much needed distraction you provided, I would have never been able to complete this research. I want to thank my roommates, as they were always the ones that had to handle my complaints during dinner. A special thanks to Daan for the fruitful discussions on both relevant and irrelevant topics, and the feedback on my work.

With this thesis, my time in Delft has come to an end. During the last six years I got the opportunity to spend a semester in Hungary and I did an internship in Australia. A massive thanks to all the people I came across during this period that made me feel at home in Delft, at the faculty, in Budapest as well as in Canberra. I enjoyed every second of my student life and will certainly miss it, but I am also very excited about the first steps of my professional career!

This page is intentionally left blank

Executive summary

The acute obstetrics (AO) sector in the Netherlands faces challenges caused by recent developments. To start with, it is increasingly difficult to find personnel and the number of hard-to-fill vacancies has seen a new high in 2018. This forces hospitals to sometimes temporarily close down parts of their total bed capacity. Furthermore, several hospitals were closed down recently, bringing down the number of AO locations from 84 in 2015 to 78 by the end of 2018. These developments put pressure on the remaining AO locations as these cannot handle the increasing inflow of patients. About two thirds of midwives has reported to call multiple hospitals before finding a hospital that has a bed available. Consequently, 80% of pregnant women does not deliver at the preferred hospital. These developments have raised questions about the performance of the sector and, more specifically, on the accessibility of AO care in the country.

There are several methods in place to assess the geographical accessibility or the spatial distribution of AO locations in the Netherlands. The National Institute for Public Health and the Environment (RIVM), commissioned by the government, annually publishes a sensitivity analysis for the AO sector. In this sensitivity analysis, an accessibility measure that is related to the so-called minimum distance measure is used. From every location in the Netherlands, the travel time to the closest AO location is calculated to keep track of sensitive AO locations. An AO location is marked as 'sensitive' if, in case of closure, the number of people that cannot reach an AO location within 45 minutes by ambulance would increase. The 13 sensitive locations can, by law, not be closed down, so the government has to offer (financial) support when needed. However, this measure is based on the theoretical assumption that a patient can and does visit the nearest AO location. As a consequence of the beforementioned developments, the closest hospital may not be an option for a patient. This effect cannot be captured by the accessibility measure in place. There seems to be a gap between the accessibility measures and the actual problems in the sector.

Research problem and approach

To fill this gap, the concept of substitutability as introduced by Van Wee and Van Cranenburgh (2017) is used in this study. Substitutability measures the extent to which the preferred alternative can be substituted by other less preferred alternatives. Substitutability is based on the well-known LogSum accessibility measure. The mathematical model of substitutability offers a possibility to evaluate the effect of elimination of the favourite option, or in other words that of the unavailability of the preferred AO location. This research aimed at analysing the performance of the spatial distribution of AO care by applying this new subject of substitutability. The following research question was formulated:

> *What are the consequences of including the concept of substitutability in the evaluation of the spatial distribution of acute obstetrics locations in the Netherlands?*

To be able to answer the research question, it was needed to calculate the accessibility and substitutability values. The substitutability model requires the following input: estimated travel time and travel cost parameters and a travel time and travel cost origin-destination matrix. The model parameters can be derived from a discrete choice model. To estimate a discrete choice model, it was decided to conduct a stated choice (SC) experiment. Therefore, before being able to answer the research question, the following four main steps have been taken.

First of all, a literature study has been performed to get an overview of the current situation in the (acute) obstetrics care sector in the Netherlands. Two more literature reviews were conducted, on accessibility measures and hospital decision making. The latter review helped shape the SC experiment, as it provided an overview of factors women consider when choosing a preferred hospital to deliver. The second step of this research was the SC experiment, conducted among female residents of the Netherlands. The data obtained by this experiment was used in the third step, the estimation of a discrete choice model. The estimation of a linear-additive RUM-MNL model resulted in the following parameters:

$$\beta_{travel\ time} = -0.0924$$
$$\beta_{travel\ cost} = -0.0683$$

As stated before, these two parameters form part of the input required for the substitutability model. The travel time and travel cost matrices are based on the usage of the 4059 habited four-digit zip codes as origins and the 78 AO care locations as destinations. Travel distances and travel times are based on Google Maps data. The travel times have been combined with a fixed cost of €0.19 per kilometre to create a travel cost matrix. These allowed for the calculations of the substitutability values. For the sake of interpretability, the substitutability values have been normalised, which concluded the research phase.

Conclusions and recommendations for future research

The similarities and differences between the outcomes for the traditional accessibility measures and the normalised substitutability measure have been evaluated. The measures all show critical values for the islands in the north of Netherlands and the province of Zeeland. However, based on the additional areas that normalised substitutability marked as critical, the main conclusion was drawn. It is suggested to mark the UMC in Maastricht and the Treant Scheper in Emmen as sensitive as well. These hospitals do not directly affect the number of women that cannot reach an AO location within RIVMs sensitivity threshold. Nevertheless, the two hospitals show to be of critical value to the spatial distribution of AO locations. The unavailability of beds in one of these hospitals would have severe consequences for the well-being of pregnant females in these regions. The results are visualised in Figure 1. The red areas on the map show areas of which the preferred AO location cannot easily be replaced by another in case of unavailability. The blue dots represent hospitals that are marked as sensitive according to the latest update published by RIVM (Kommer, Gijsen, & Giesbers, 2019). The purple dots represent the proposed additional sensitive locations, based on the results of the substitutability model.

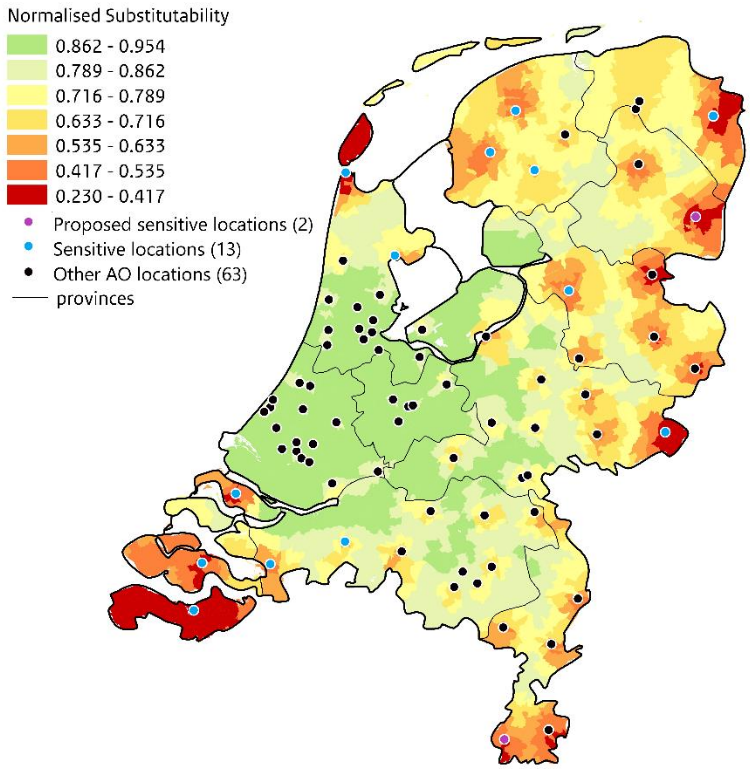


Figure 1 Normalised substitutability values and suggestions for sensitive locations

This research is to be viewed as an explorative study, as it is one of the first applications of the model to a practical case. It is important to note that the study is based on assumptions made throughout the research that may have affected the outcomes. The literature study is based on the opinion of the researcher and the sample of the SC experiment may not be representative for the population. These assumptions have caused bias on the substitutability results. Nevertheless, the study provides preliminary insights in its research field.

The study focused on AO locations, but the substitutability model has shown to have potential to be of use in other situations as well. In any situation where unavailability of the preferred alternative plays a role, it could help identify critical areas in the spatial distribution. From a more general point of view, it has been concluded that substitutability makes for a good complementary measure next to other more traditional accessibility measures. Results of both can be compared using maps. Together with the ease of application and the flexibility the model offers, substitutability is a promising future research subject. Considering the results as found in this study, some suggestions for future research are:

- Exploration of different model formulations for the substitutability calculations, besides the LogSum based model;
- Inclusion of other parameters than just cost and time parameters;
- Research from the perspective of hospitals, so instead of taking the hospital user as a starting point, taking a demand-side perspective;
- Inclusion of constraints in the substitutability model.

This page is intentionally left blank

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

	Nederlands	English
A&E	Spoedeisende hulpafdeling	Emergency medical department
ANWB	Algemene Nederlandse Wegen Bond	Royal Dutch Touring Club
AO	Acute verloskunde	Acute obstetrics
CBS	Centraal Bureau voor de Statistiek	Statistics Netherlands
fte	Voltijdequivalent	full time equivalent
GDP	Bruto binnenlands product	Gross domestic product
IGJ	Inspectie Gezondheidszorg en Jeugd	Health and Youth Care Inspectorate
Kadaster	Kadaster	Cadastre, Land Registry and Mapping Agency
KNOV	Koninklijke Nederlandse Organisatie van Verloskundigen	Royal Dutch Organisation of Midwives
LC	Latente klassen	Latent class
LRS	Waarschijnlijkheidsratio statistiek	Likelihood ratio statistic
MC	Medisch centrum	Medical centre
ML	Gemengde logit	Mixed logit
MNL	Multi nominaal logit	Multi nominal logit
msz	medisch specialistische zorg	specialist medical care
NFU	Nederlandse Federatie van Universitair Medische Centra	Netherlands Federation of University Medical Centres
NL	Geneste logit	Nested logit
NVZ	Nederlandse Vereniging van Ziekenhuizen	Dutch Hospital Association
NZa	Nederlandse Zorgautoriteit	Dutch Healthcare Authority
OECD	Organisatie voor economische samenwerking en ontwikkeling	Organisation for economic co-operation and development
OPF	Buitenpolikliniek	Outlying polyclinic facility
RIVM	Rijksinstituut voor Volksgezondheid en Milieu	National Institute for Public Health and the Environment
RRM	Willekeurige spijtminimalisatie	Random regret minimization
RUM	Willekeurige nutsmaximalisatie	Random utility maximization
SC	Gestelde keuze	Stated choice
SP	Gestelde voorkeuren	Stated preference
UMC	Academisch Ziekenhuis; Universitair Medisch Centrum	Academic Hospital; University Medical Centre
VoTT	Betalingsbereidheid voor reizen	Value of travel time
VWS	Volksgezondheid, Welvaart en Sport	Health, Welfare and Sport
ZKN	Zelfstandige Klinieken Nederland	Independent Clinic Netherlands
ZN	Zorgverzekeraars Nederland	Dutch Health Insurers
ZVW	Zorgverzekeringswet	Health Insurance Act

This page is intentionally left blank

1 Introduction

In the Netherlands, the Ministry of Health, Welfare and Sport (VWS) is responsible for the health and welfare of citizens. The ministry seeks to support people who have health problems and tries to make sure these people can "call on their general practitioner, the hospital or other forms of health care on time" (VWS, 2018, p. 20). The health care system of the Netherlands allows for regulated competition (Hoogervorst, 2004). The introduction of competition was aimed at enhancing three government-defined goals: quality, accessibility and affordability of the health care system (Van den Berg, De Boer, et al., 2014; VWS, 2018). Historically, the Netherlands has scored relatively well on accessibility measures when compared to other Organisation for Economic Co-operation and Development (OECD) countries (Ruwaard, 2018; Van den Berg, De Boer, et al., 2014).

According to the accessibility model developed by the National Institute for Public Health and the Environment (RIVM), 99.6% of all citizens can reach an emergency medical department (A&E) by car within just 30 minutes (RIVM, 2018b). By ambulance, 99.8% of the citizens can reach an A&E within 45 minutes. These relatively good scores on accessibility of health care in the Netherlands can partly be explained by the high population density and the distribution of ambulance stations. The population density of 509 people per square kilometre is the highest of all OECD countries (The World Bank, 2017). Furthermore, the integral approach and the yearly revision of the ambulance distribution helps improve the overall system (Kommer & Mulder, 2018).

However, recent bankruptcies of several hospitals have raised concerns amongst citizens. The Medical Centre (MC) Slotervaart in Amsterdam and all four establishments of the MC IJsselmeerziekenhuizen in Lelystad, Emmeloord, Dronten and Urk are planned to be closed down in the near future (Bruins, 2018). As another 12 out of 68 analysed hospitals turned out to be financially unstable, minister for Medical Care and Sport Bruno Bruins asked RIVM to research the effect of the closures on the spatial distribution of the national hospital sector (BDO, 2018; Bruins, 2018).

Another alarming recent development has put pressure on the health care system. Several hospitals struggle to find personnel and the number of hard-to-fill vacancies has seen a new high in 2018 (BDO, 2018; Leensen, Poulssen, & Weststrate, 2018; Van den Berg, Kringos, Marks, & Klazinga, 2014). Consequently, hospitals are sometimes forced to temporarily close down parts of their total bed capacity (Weeda, 2018a, 2018b). Sometimes the closest hospital simply does not have a bed available for a certain patient (Wassenaar, 2017). The accessibility measures in place assume patients receive treatment at the nearest hospital (Van den Berg, De Boer, et al., 2014). Concludingly, there seems to be a gap between the accessibility measures and the actual problems in the hospital sector.

1.1 Research problem

As discussed, there is a need for additional insights in the performance of the Dutch hospital sector from an accessibility point of view. Accessibility of health care is one of the three major objectives of the Ministry of VWS (VWS, 2018). The yearly updates by RIVM on the performance of the hospital sector include accessibility measures such as 'travel time to the nearest hospital by car' and 'travel time to the nearest A&E by ambulance' (Kommer & Mulder, 2018; RIVM, 2018a). Furthermore, by law, the government has the obligation to (financially) support hospitals that are marked as 'sensitive'. A hospital is marked as sensitive "if, according to the theoretic model, the number of residents that may take more than 45 minutes to be brought to an A&E increases when this hospital closes." (Kommer, Gijsen, De Bruin-Kooistra, & Deuning, 2017, p. 5).

These models and performance measures are all based on the assumption that the patient visits the nearest hospital. More importantly, it assumes the patient concerned can receive the required aid at the nearest hospital. However, as a consequence of the aforementioned developments, the closest hospital may not be an option for a patient. To what extent do patients experience a loss of accessibility if the nearest hospital is not available? To fill this gap, the concept of substitutability as introduced by Van Wee and Van Cranenburgh (2017) could provide interesting insights for the hospital sector in the Netherlands. The mathematical model for substitutability offers a possibility to assess the effect of elimination of the favourite option, or in other words that of the unavailability of the nearest hospital. The concept is elaborated on further in Section 1.6.4. The next section will first zoom in on the scope of this research project.

1.2 Research scope

The scope of this research is to identify the potential added value of the substitutability concept for the spatial distribution of the health care sector in the Netherlands. In some areas, a cross-border trip to a hospital is a feasible possibility. For example, the General Hospital in Turnhout is only 12 km from the Belgium – Netherlands border. However, as basic health insurances solely cover health care costs made in the Netherlands, foreign hospitals are outside the scope of this research.

The focus of this research project is on acute obstetrics (acute verloskunde (AV) or AO) locations. In December 2018, 78 hospitals provided 24/7 AO care (Kommer & Mulder, 2018). Unavailability of beds in this department poses a serious threat to the health of both the pregnant woman as well as the unborn baby (Muller, 2019). There is no publicly available data on the times bed capacity forced a pregnant woman to go to another hospital. However, a survey by the Royal Dutch Organisation of Midwives (KNOV) states 80% of pregnant women does not deliver in the preferred hospital and about two thirds of the midwives has to call multiple hospitals before finding an available bed (KNOV, 2018). This makes for an interesting case for the application of substitutability as a spatial distribution concept.

Furthermore, RIVM has thoroughly researched the spatial distribution of AO locations, which offers the possibility to compare results. Obstetrics services can be divided into planned and acute care (G. J. Kommer, personal communication, January 18, 2019). Transportation for AO is partly done by ambulance, but the majority is done by private transport (Gijsen, Kommer, Bos, & Van Stel, 2010). Trips for planned obstetrics care are assumed to be done by private transport. Therefore, the focus of this research is on car transport, as it is assumed pregnant women in need of (A)O care come to the hospital by car. This again makes results comparable to existing research.

Finally, this research has to be approached as an explorative study, as it includes an early application of substitutability. To the best of the authors knowledge, besides the work by Van Wee, Van Cranenburgh and Maat (2018), this has not yet been done. Based on the research scope, the objective of this thesis project is presented in the next section.

1.3 Research objective

The main purpose of this thesis is to evaluate the spatial distribution of hospitals, more specifically of the AO locations in het Netherlands. There are accessibility measures in place at the moment, which is compared to the concept of substitutability as introduced by Van Wee and Van Cranenburgh (2017). Substitutability has the potential to indicate other critical areas in the spatial distribution than the other accessibility measures currently in place. These criticalities could lead to recommendations regarding the locations to be marked as ‘sensitive’.

Additionally, the focus of the study is on researching the robustness of the spatial distribution by means of the substitutability concept. It is tested whether substitutability is better suited for the evaluation of the AO location distribution than the measures currently used. It is explored whether substitutability could replace measures or should be applied as a complementary measure. To the best of the authors knowledge, substitutability has not yet been explored thoroughly, let alone in the hospital sector. According to Yin (2014), when the existing knowledge base on a certain topic is not sufficient (yet), a new empirical study will most likely be an exploratory study. Therefore, the study focuses on exploring the concept rather than on developing general theoretical statements. To reach this goal, the next section presents the main research questions and the appurtenant sub-questions.

1.4 Research questions

Considering the research objective and the scope of the thesis project, the main research question is defined as follows:

> *What are the consequences of including the concept of substitutability in the evaluation of the spatial distribution of acute obstetrics locations in the Netherlands?*

In order to answer this question, it is necessary to define sub-questions on the different topics of the main research question. These will be introduced, after which the methodology per question will be elaborated on further.

1. How is the current acute obstetrics care system of the Netherlands organised, and how has its spatial distribution developed over the last decade?
2. Which factors influence the decision for women in the Netherlands when choosing a hospital for acute obstetrics care, and to what extent?

3. What are the differences between the values for accessibility and substitutability in the spatial distribution of the acute obstetrics locations in the Netherlands?
4. What is the added value of including substitutability in a spatial distribution analysis?

The main objective of answering the research questions is to provide preliminary insights in how substitutability can be a relevant concept when evaluating travel behaviour. The next section will briefly elaborate on the relevance of this research, after which Section 1.6 presents the different research methods that will guide answering the research questions.

1.5 Relevance of the research

From a scientific point of view, by comparing substitutability to the accessibility measures, this thesis will contribute to spatial distribution research and more generally to travel behaviour research. As discussed, the concept of substitutability has barely been researched in a travel behaviour context, let alone included in spatial distribution analysis. Therefore, this thesis serves as a first exploration of the particular scientific subject. Ideally, the outcomes will help other scientists in future research projects on substitutability or other accessibility topics.

The research project is relevant in societal terms as well, as health care is a public good. Furthermore, the outcomes might be helpful for governmental research institutions such as RIVM. It is however not the intention of the research to come to practical policy advice or recommendations. Rather, the focus is on investigating the substitutability subject, the consequences of including it in the analysis and its potential added value.

1.6 Research methods

The intention is to approach the developed research questions with the use of multiple methods. To be able to calculate the accessibility and substitutability values, input parameters for the substitutability model are needed. These include estimated model parameters, amongst others. The study can roughly be divided into five different steps. In the upcoming sections, a short description of the different methods used in these steps will be presented. When applied, each method will be elaborated on further in the appurtenant chapter.

1.6.1 Literature review

The first step of the study consists of a literature review. The aim is to answer the first sub-question and a part of the second sub-question. A study of existing literature on AO, accessibility measures used in the hospital sector and hospital decision making will be performed. For the former subject, mostly governmental publications will be used. The review of accessibility measures will be narrowed down to hospital spatial distribution measures. For the review of hospital decision making, a step-by-step review plan will be attached, as the base of literature on this field is very large.

Sub-question 1: What does the current acute obstetrics care system of the Netherlands look like, and how has its spatial distribution developed over the last decade?

First of all, the hospital sector and more specifically the AO sector of the Netherlands will be reviewed. The objective is to get a well-founded understanding of recent developments and the current situation. A thorough study of the field will provide an overview of the current spatial distribution, which will help answer the first sub-question. The expectation is that most of the required information will be found in governmental publications and research done by for instance RIVM. The performance measures of the spatial distribution of the health care sector will also be included in the review, as these will be helpful for the comparisons to be made in a later stage of the research and will help identifying the potential added value of substitutability for this sector.

Sub-question 2: Which factors influence the decision for women in the Netherlands when choosing a hospital for acute obstetrics care, and to what extent?

For the second sub-question, a literature study will serve as a base for the answer. A review of existing literature on hospital decision making is crucial for the identification of factors that play a role for women choosing obstetrics care. The literature review is started from a broad perspective, including state-of-the-art hospital decision making research from international journals. Databases like ScienceDirect, Scopus and Google Scholar will be used. After completing the literature studies, an overview of important decision-making parameters is formulated. However, it is expected the existing literature does not include research on parameters for AO decision making in the Netherlands specifically. These will have to be found using a survey among female residents of the Netherlands. Stated choice experiments are a suitable way to identify a cost and travel time parameter, as will be explained in the next section.

1.6.2 Stated choice experiment

To finalise the answer to the second sub-question, a survey will be used. To identify the preferences of women when choosing an AO hospital, a stated choice (SC) experiment will be conducted. As stated by Louviere, Hensher and Swait (1998), SC experiments intend to examine behaviour of people. The results comprehend trade-offs in their decision-making. In this survey, trade-offs could for example be the perceived quality of a hospital or the preference for a general hospital instead of an academic hospital (UMC). In a SC experiment, the questioned participant will be asked to choose between multiple (hypothetical) choice situations (Train, 2002). By comparing the stated choices, the resulting data enable the estimation of user preference parameters (Kroes & Sheldon, 1988).

As the substitutability model requires travel time and travel cost parameters, another objective of the SC experiment is the identification of a Value of Travel Time (VoTT). The VoTT is the marginal rate of substitution between travel time and cost in choice models (Brownstone & Small, 2005; De Jong, Tseng, Kouwenhoven, Verhoef, & Bates, 2007). The VoTT serves as input for the next sub-question. It is part of the model that is the base for the substitutability values. SC experiments are often applied to derive the VoTT (Brownstone & Small, 2005; Devarasetty, Burris, & Douglass Shaw, 2012).

It should however be noted that there are a few limitations to the application of the SC method. First of all, as the experiments regard stated responses, it is unsure how people will behave in reality. One should also be aware of the fact that respondents might behave strategically, aiming to influence future policy making (Molin, 2010). A possibility to solve this issue is to validate using revealed behaviour studies, instead of SC experiments. This is nevertheless out of scope for this research project.

Concludingly, the SC experiment supplements the outcomes of the literature study. Together, they provide an answer to sub-question two. Ideally, the outcome of the SC experiment is a discrete choice model with significant parameters that can directly be used as input for the substitutability model.

1.6.3 Discrete Choice Modelling

To be able to identify the VoTT and estimate a model to use for substitutability, discrete choice modelling will be used. Discrete choice modelling allows for estimation of a model based on observed choices of a SC experiment (Molin, 2010). Most discrete choice models are derived under the assumption of utility-maximising behaviour by decision-makers (Train, 2002). The model and appurtenant parameters will allow for estimation of choice probabilities. Initially, Van Wee and Van Cranenburgh (2017) used the logit-formula to predict choice probabilities. This method is also used for the data gathered in the SC experiment of this study.

Based on the choice probabilities of the hypothetical hospital alternatives, the different input parameters for the substitutability calculations will be gathered. The next section discusses the different values for substitutability and accessibility that will be calculated in order to answer the third research sub-question.

1.6.4 Results comparison

Before explaining this fourth step of results comparison, that will help answer the third sub-question, the obtained results will be discussed briefly. First of all, the accessibility measures. The accessibility of AO locations will be calculated, in other words the time it takes to get to an AO location. RIVM also frequently assesses the spatial accessibility of different acute departments of the health care system of the Netherlands (RIVM, 2018a). These accessibility measures are based on car drive time matrices, from origin (home) to destination (hospital). This data is unfortunately not publicly available, so it will have to be recalculated in order to make the results comparable.

Secondly, the substitutability calculations. As discussed briefly before, substitutability is a relatively new mathematical concept that offers the possibility to value the unavailability of the preferred alternative. Substitutability is very closely related to accessibility and Van Wee et al. (2018) proposed a definition in the context of travel behaviour. According to Van Wee, Van Cranenburgh and Maat (2018, p. 2), substitutability is “the extent to which the preferred travel alternative can be substituted by other initially less preferred alternatives.”. More specifically, this means it offers a mathematical model to assess the unavailability of the preferred AO care centre.

Choice probabilities of different alternatives form the required input. Further explanation of the concept and the mathematical formulation can be found in Section 4.1.

Sub-question three: What are the differences between the values for accessibility and substitutability in the spatial distribution of the acute obstetrics locations in the Netherlands?

Comparing both measures may offer new insights in the performance of the acute obstetrics spatial distribution in the Netherlands. This will be captured in the answer to the third sub-question. The fourth and last sub-question includes a more general approach to the substitutability concept. Ideally, it offers insights in the potential added value of applying the concept in other areas then acute obstetrics. The objective is to capture these insights in the answer to the last sub-question.

Sub-question four: What is the added value of including substitutability in the spatial distribution analysis of AO locations?

The use-case to AO locations is to be viewed as an explorative application. Nevertheless, the goal is to identify insights in the substitutability concept that may be generalizable. These insights will be helpful to future researchers that intend to research substitutability from a travel behaviour perspective.

1.6.5 Conclusion

The last step in this research is to draw final conclusions. After identification of variables that influence the choice for a specific AO centre, the choice probabilities are described in a specific choice model. The outcomes of the accessibility and substitutability will then be compared. This will guide the identification of the potential added value of substitutability, which will answer the main research question. This also concludes the final phase of the research report.

1.7 Report structure

The thesis report is structured based on the steps as explained in Section 1.6. In Chapter 2, the (theoretical) background is introduced by means of literature studies. Chapter 3 explains the different steps of the SC experiments and the results. In the third chapter, discrete choice modelling will help identify the input for substitutability and accessibility. These substitutability steps and results will then be discussed in Chapter 4. The last chapter, Chapter 5, takes on the conclusions, future research recommendations and a reflection. An overview of the different steps, including input, used software packages and output is given in Figure 1.1.

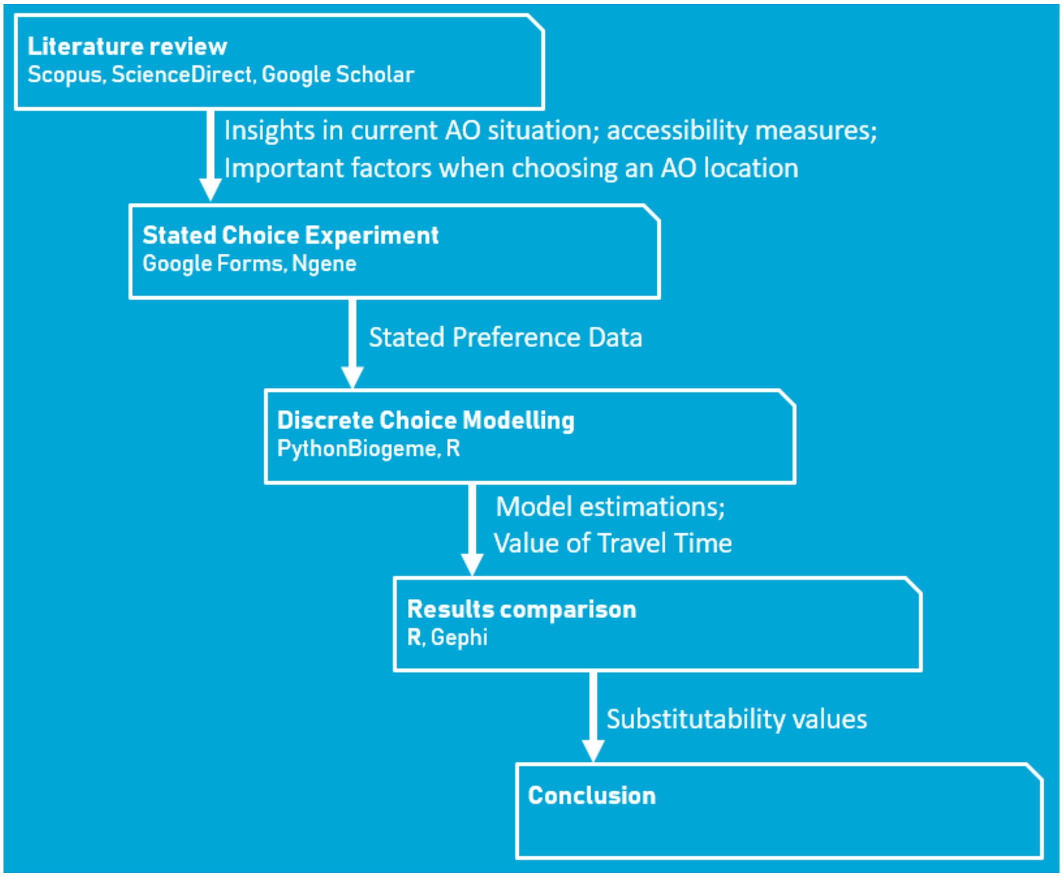


Figure 1.1 Steps to be taken in this research, including software to be used

2 Theoretical background

As mentioned in Section 1.6.1, this chapter will elaborate on the background of this research by means of a literature review. The chapter will start off by presenting the main characteristics of the hospital sector in the Netherlands. The subsequent Sections 2.1.1 and 2.1.2 respectively elaborate on recent developments and the spatial distribution of AO locations. In Section 2.2, the relevant accessibility indicators currently in use will be presented. The last part of this chapter, Section 2.3, will review the variables that influence hospital decision making according to existing literature.

2.1 The hospital sector in the Netherlands

As discussed in Chapter 1, the Dutch health care system is based on three principles: access to care for all, solidarity through the compulsory medical insurance and high-quality healthcare service (VWS, 2016). In 2006, the reformed Health Insurance Act (ZVW) was introduced. This implied the obligation to pay a monthly fee towards the collective health insurance costs of the country. This compulsory insurance package covers basic health care costs. Consequently, the majority (83%) of the total expenditures on specialist medical care (msz) (€27.2 billion in 2017) is financed by the ZVW. It is possible to supplement the basic insurance package with an insurance for additional health care. This additional package is not compulsory.

Despite the private character of the health care sector, the sector is quite strongly regulated. For this reason, the government keeps an eye on the spatial distribution of the hospital locations. RIVM annually brings out a report on the supply and accessibility of emergency hospital care in the Netherlands. In this report, the locations of all A&E and AO departments are analysed to check if the distribution requirements are still met.

The public hospital sector in the Netherlands can be divided into four different categories. Regular hospitals, outlying polyclinic facilities (OPFs), academic hospitals and children's hospitals. RIVM regularly updates the online list of hospitals and their locations. The last update dated from June 2018, so the list has been updated manually based on recent updates about hospital closures, merges and moves. The six children's hospitals as found in the list published by RIVM (2018c) are located in Utrecht, Rotterdam, Nijmegen, Amsterdam and Leiden and are connected to one of the UMCs. One children's hospital is found in The Hague but is for unknown reasons not recognized in RIVMs list of hospitals as being a children's hospital. The hospital has nevertheless been included in the list as a children's hospital. The different OPFs belong to either a general or an academic hospital (Volksgezondheidenzorg.info, 2018b). The total number per type of facility in December 2018 can be found in Table 2.1. Considering the seven children's hospitals are located at either a general or an academic hospital, this brings the total amount of hospital locations to 239.

Table 2.1 Types and number of public hospital facilities in the Netherlands, update December 2018 (adapted from RIVM, 2018)

Type of Hospital	Amount
Academic Hospital (UMC)	8
General Hospital	100
Outlying Polyclinic Facility	131
Children's Hospital	7
Total	**246**

Besides the public hospital facilities, the Netherlands also has a large amount of private health care centres. The majority of these clinics are specialised in either dermatology or ophthalmology. The private health care sector is not very well-documented, but Independent Clinics Netherlands (ZKN) has registered 358 clinic locations and the Health and Youth Care Inspectorate (IGJ) monitored 418 clinics in 2016 (IGJ, 2016; Zelfstandige Klinieken Nederland, 2018).

About 15.6% of the total jobs in the Netherlands in 2017 were in the health care and welfare sector. The total employment in the msz equalled 229,600 full time equivalent (fte), which is about 30% of the fte in health care. The total number of employees in the general hospitals was about 211,700 (Nederlandse Vereniging van Ziekenhuizen, 2018). Concludingly, the health care sector is a very important labour sector from two perspectives. On the one hand, hospitals and other health care facilities are major employers, which offers employment opportunities. On the other hand, it is of social importance to make sure the health care sector works at a sufficient capacity. This latter challenge and other important developments will be elaborated on in the next section.

2.1.1 Recent developments

This section will elaborate on several recent developments in the msz sector. The different bullet points are intended to group together some of the developments and the associated consequences. All these developments are somehow interrelated and should therefore not be viewed as stand-alone events.

- Financial developments

Over the last decade, the annual expenditures on health care have increased by almost 20% to more than €90 billion in 2017. While this seems extremely high, the percentage of Gross Domestic Product (GDP) spent on health care has stayed relatively stable in the same period as can be seen in Figure 2.1. The expenditures are expected to increase to €137 billion in 2040. This is mainly due to demographic changes: the life expectancy is increasing which leads to higher elderly care costs. The other two third of the increase in expenditures is to be attributed to developments of medical technology and economic growth (RIVM, 2018c).

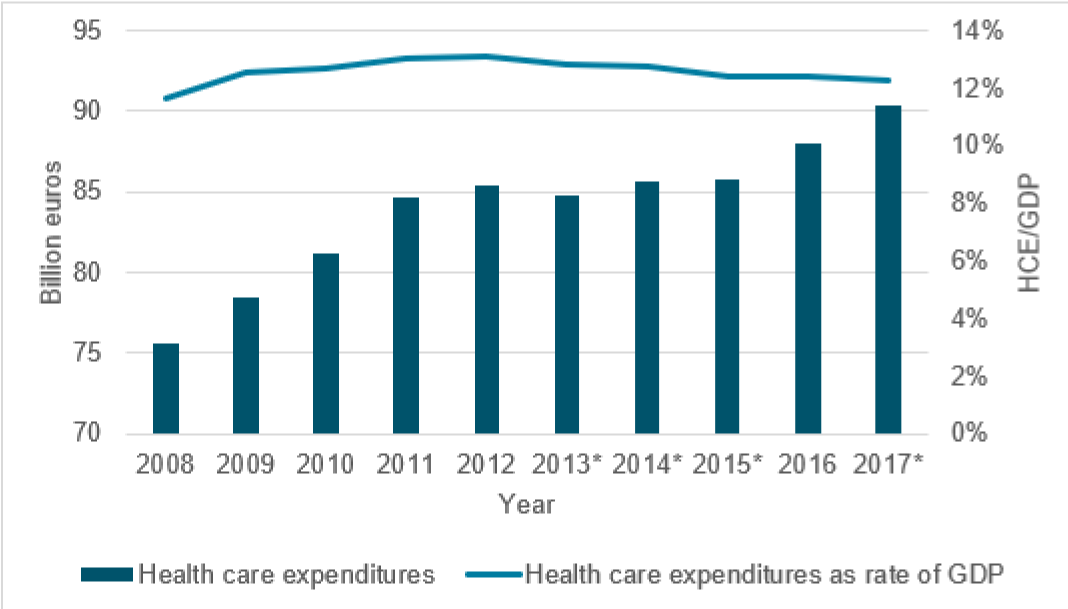


*Figure 2.1 Annual health care expenditures, 2008 - 2017 (adapted from CBS, 2018) Note: * are estimated figures*

The growing costs prompt pressure on health care providers to work more efficiently. Nevertheless, hospitals have struggled to stay financially healthy for years. According to the benchmark BDO presents annually, the return of the 66 studied hospitals has been decreasing steadily (BDO, 2018). Furthermore, 14 hospitals were on the verge of bankruptcy in June 2018. Two of these had to be closed in the end of 2018. Many people in the region have shown their worries (Oosterom, 2018; Oosterom & Van de Wier, 2018). Despite the fact that RIVM closely monitors the spatial distribution, a major concern is that of accessibility of (acute) health care services for citizens.

Finally, the number of hospital mergers has peaked in 2015. The most frequently mentioned arguments for mergers are improvement of efficiency by concentrating top clinical specialists and quality improvements (NZa, 2015). However, as has been investigated by Batterink, Reitsma, Bakker, Pomp and Plu (2016), it is difficult to determine the effects of mergers on quality. BDO concluded a decreased solvability, liquidity and return for five of the eight hospitals that merged in 2015. Apparently, merging does not guarantee financial stability. Other potential risks are “the limitation of choice possibilities for patients, longer travel times, lower quality and higher tariffs” (Fusies tussen ziekenhuizen Volksgezondheidenzorg.info, 2018a). The changes in the distribution may have a major impact on accessibility of health care for patients, so one could question how advantageous mergers really are.

- Personnel and capacity problems

Another development that puts pressure on the financial outlook of hospitals is the struggle to find suitable personnel. The number of hard-to-fill vacancies has peaked in 2018 (BDO, 2018; Leensen et al., 2018). Furthermore, the total number of vacancies has doubled in the last four years (Nederlandse Vereniging van Ziekenhuizen, 2018). In order to temporarily solve these problems, health care institutions regularly have to hire freelancers. Most institutions have however reported this is undesirable, as hiring freelancers does not promote continuity and requires a lot of adaptivity of their own personnel (Van den Brink, Herderschee, & Vleugels, 2018).

To gain insights in the opinions and feelings personnel has, several institutions spread surveys among nurses such as RIVM and Netherlands institute for health services research (NIVEL). Some worrying developments that represent the increasing pressure on nurses are shown in Figure 2.2. The effects of the increasing pressure on hospital personnel has led to an absenteeism rate of almost 6% in 2017. Together with a new five-year high staff turnover of 13.3%, the majority of hospitals is now facing challenges in terms of capacity (Leensen et al., 2018).

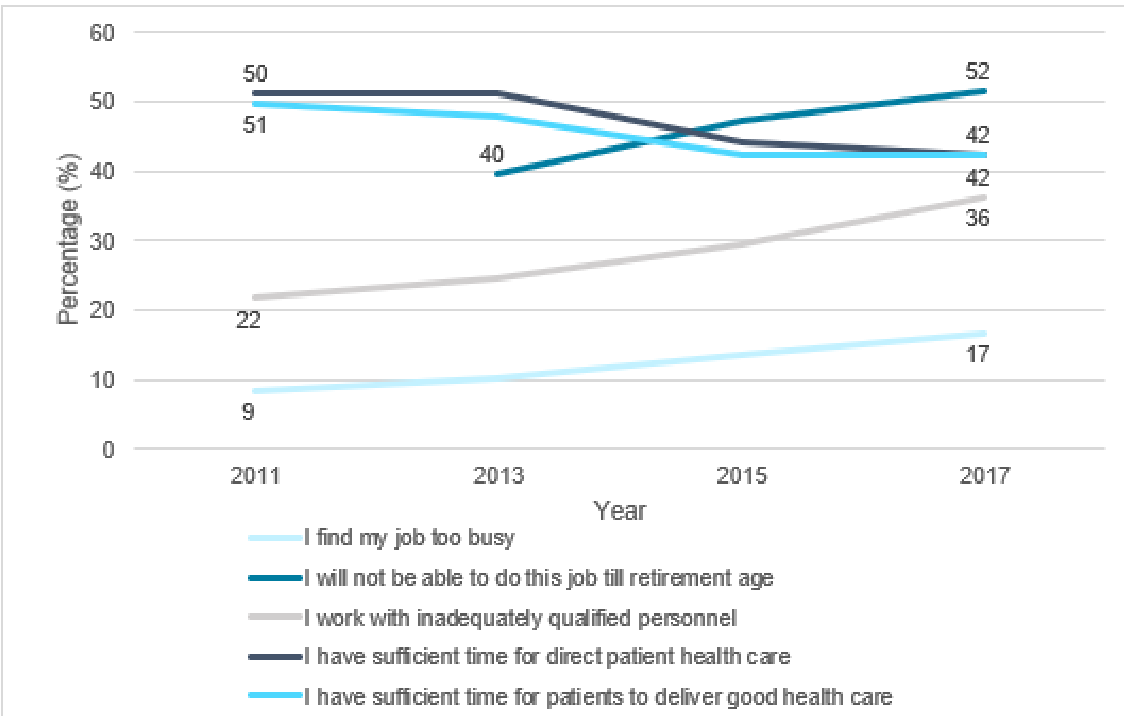


Figure 2.2 Survey results among nurses, 2011 - 2017 (adapted from NIVEL, RIVM and CBS)

These capacity complications have had an impact in almost every hospital, on both acute as well as non-acute services. About half of the hospitals reported they had to postpone planned surgeries (Van den Brink et al., 2018). According to the head of the intensive care department at the ErasmusMC in Rotterdam, they "sometimes have to postpone an acute heart surgery because there is no intensive care bed available." (Weeda, 2018a, p. 2). In 2018, all UMCs have reported to limit their bed capacity. General hospitals also are sometimes forced to temporarily close down parts of their total bed capacity (Weeda, 2018a, 2018b). Concludingly, the lack of capacity is two-folded, as on the one hand the operation theatres are short-staffed, while on the other hand bed capacity sometimes has to be limited. As a consequence, the waiting times for both diagnosis as well as treatment have grown to five-year highs (Mediquest, 2019). In recent interviews, the Dutch Hospital Association (NVZ), the Netherlands Federation of University Medical Centres (NFU), the minister for Medical Care Bruno Bruins, the Dutch Health Insurers (ZN) and the Dutch Healthcare Authority (NZa) stated this is worrisome (Kempes & Bunskoek, 2019).

- Shifts in health care provision

Several other changes that influence the spatial distribution of health care services have happened over the last couple of years. The tremendous growth in OPF locations and the increase in the number of private clinics are discussed briefly.

Over the last decade, the amount of OPFs has grown by 120% from 61 in 2009 to 131 in 2018 (Volksgezondheidenzorg.info, 2018b). Most of these are located on the edge of the catchment area of a particular hospital, to compete with hospitals in the vicinity. These developments seem positive for the distribution of health care services. It offers patients the possibility to visit a nearby OPF location instead of the further located general hospital. One could argue if the purpose of OPFs is competing with other hospitals rather than to get closer to their own patients and enhance accessibility (Sonneveld & Heida, 2014). However, the effect of opening multiple OPFs is expected to improve accessibility of healthcare.

Secondly, private clinics have gained popularity of the last couple of years. The Netherlands has also seen an increase in private clinic locations. The growth in this sector is captured in Figure 2.3. Despite the fact that most of the clinics are located in the Randstad, the increasing number of clinics improves the spatial distribution of healthcare (Zelfstandige Klinieken Nederland, 2018). Furthermore, the waiting times for private clinics are usually a lot lower than those of regular hospitals. However, private clinics usually focus on one particular discipline. For acute health care, the Dutch citizen still has to visit a general hospital.

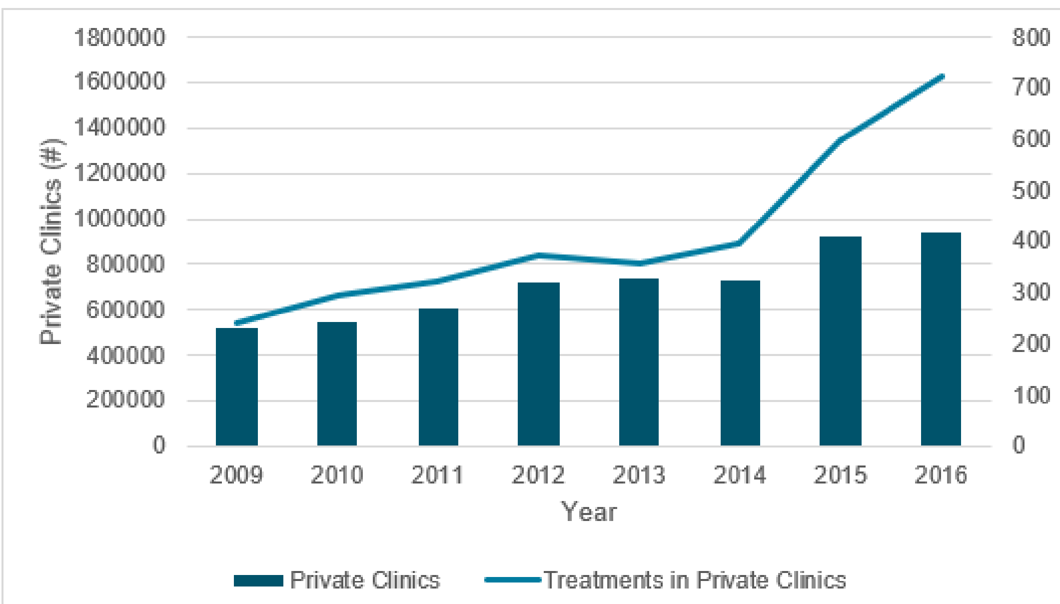


Figure 2.3 Number of (treatments in) private clinics, 2009 - 2016 (adapted from IGJ)

Concludingly, the beforementioned developments have all, some to a lesser extent, had their influence on the spatial distribution of healthcare in the msz sector. The next section will zoom in on the main characteristics and developments of the (A)O care sector specifically.

2.1.2 The current situation of AO

Over the last twenty years, the number of women that delivers at home has declined tremendously. Only 13 percent of women gave birth at home in 2015, compared to 23 percent in 2005 (Perined, 2017). The Netherlands is one of the only countries where a delivery at home is this popular. In other countries, hospital deliveries are the standard. It seems the Netherlands is shifting to this standard as well. The shift towards hospital deliveries could maybe be explained by the fact that the Netherlands was one of the six countries with the highest percentage of perinatal deaths in Europe in 2010. This percentage has improved from 9 permille to 4.2 permille in 2015 (Euro-Peristat, 2018).

According to research by TNO, dating from 2008, this shift towards hospital deliveries as the standard worries women as they sometimes would need to travel far to the nearest hospital (Volkskrant, 2017). Furthermore, it is questionable whether or not the sector can handle this shift. To be marked as a hospital that provides AO care, a hospital needs to meet the following three requirements:

1. AO 24 hours a day 7 days a week,
2. Presence of clinical obstetrician or gynaecologist, and
3. Gynaecologist, paediatrician, anaesthesiologist, nurse anaesthetist and operating room available within 30 minutes (Kommer et al., 2017).

The number of AO care hospitals that meet these requirements has decreased from 84 in 2015 to 78 by the end of December 2018 (RIVM, 2018b). The Treant Zorggroep for instance was forced to close down two of their AO locations (in Stadskanaal and Hoogeveen) because of the deficiency of available paediatricians in the region (RTVDrenthe, 2018). Media reported on the worries of people living in the areas next to the hospitals that have either closed down their AO or are on the verge of closing down (Muller, 2019; RTVDrenthe, 2018; Van de Wal, 2019; Van Lonkhuyzen, 2019; Van Steenbergen & Weeda, 2018).

Besides the worries expressed by residents of affected areas, midwives and hospitals have also expressed apprehension regarding the current situation for AO. The main concern is regarding available personnel. The most hospitals report a sufficient number of beds, but unavailability of personnel to actually make use of this capacity. This development comes with an increased pressure on midwives (Molenaar, 2018; Van den Brink & Herderschee, 2018). Midwives state they often have to call multiple hospitals before being able to bring a woman, who is about to give birth, to a hospital (KNOV, 2018; Van den Brink & Herderschee, 2018).

The additional inflow in some hospitals caused by the closure of other AO locations, combined with the unavailability of personnel have led to an increase in travel time to AO locations (RTLNieuws, 2019; Van Steenbergen & Weeda, 2018). This development has not passed by unnoticed by the minister for Medical Care Bruno Bruins. However, theoretically speaking, no laws or agreements have been broken yet as the spatial distribution of AO locations in the

Netherlands still meets the requirements. The next section will discuss the results of the literature study on different accessibility indicators for the spatial distribution of hospitals.

2.2 Accessibility indicators

There are several methods to assess the performance of a system or a specific spatial distribution. Some of these focus on optimization of the hospital location network, such as the covering model. This model is based on maximization of the sum of hospital patients covered within a certain distance. For example in France, this model has been applied to maternity hospitals by Baray and Cliquet (2013). In a case study in New Mexico, a similar approach was used on emergency departments (Tokar Erdemir, Batta, Rogerson, Blatt, & Flanigan, 2010). Nevertheless, these models rely on simulations: it is often not practically feasible to fully optimize hospital locations in a certain area. Although there is a lot more at stake than is used in theoretical models, geographical accessibility measures like these have been part of federal health legislation for a long time (Smith et al., 1985). However, this research focuses on insights in the current situation rather than on optimization of the distribution.

In this light, several types of geographical accessibility measures have been applied to health care sectors. Table 2.2 includes a recapitulatory overview of six of these measures based on other comprehensive reviews (see e.g. Bhat et al., 2000; Hanson & Schwab, 1987; Joseph & Phillips, 1984; Love & Lindquist, 1995; Martin & Williams, 1992)

Table 2.2 Summary of accessibility measures for the hospital sector (adapted from Love & Lindquist and Martin & Williams)

Measure	Description
Choice-set	Number of hospitals within a certain distance of location or person
Extended choice-set	Choice-set, but with additional factors included. E.g. distinction between rural and urban areas
Minimum distance	Distance to closest hospital
Mean distance	Average of the distances to each of the hospitals weighed by the probability of usage
Hansen	Inclusion of the attractiveness of hospital, reflecting the propensity to travel for hospitals
Log-sum	Hansen measure, with the inclusion of a natural logarithm

In the Netherlands, Statistics Netherlands (CBS) applies the choice-set method as it keeps track of the number of hospitals within a certain reach on a provincial as well as a municipal level (CBS, 2019d). For the AO distribution specifically, there are two measures in place that are related to the minimum distance measure as presented in Table 2.2. One is focused on ambulance trips, the other is focused on accessibility by car. The former measure also holds for A&E. For emergency care (both A&E and AO) the so-called 45-minute rule is used. This means, in case of an emergency, any resident of the Netherlands should be able to get to an emergency department within 45 minutes. The 45 minutes include the 15 minutes it should, to the utmost, take to get to a patient in need by ambulance (Kommer et al., 2017). Recently, the minister for Medical Care Bruno Bruins called this rule outdated and advocated for a revision of the rule. He also stated the norm should be viewed as a directive rather than a strict rule. These statements lead to insurrection, as the Area Health Department of the province of Flevoland recently announced their average ambulance trip time to be 51 minutes (Lengton, 2019). As there is no publicly available data on ambulance driving times, it is difficult to objectively judge the statements made by minister Bruins.

The focus of this research will also be on driving times by car. The accessibility measures serve as a guide for identification of the so-called sensitive hospitals. A hospital is marked as sensitive "if, according to the theoretic model, the number of residents that may take more than 45 minutes to be brought to an increases when this hospital closes." (Kommer et al., 2017, p. 5). In April 2018, the total number of sensitive hospitals is ten for basic A&E and thirteen for AO (RIVM, 2018b). The mentioned theoretical model is the accessibility model, according to which the distribution of hospitals covers 99.8% of the residents of the Netherlands (Kommer et al., 2017).

In the case of AO, it is said to cover 99.7% of women in the fertile age, which is from 15-50 years according to CBS (2019a). In other words, 99.7% of women in the fertile age can reach a hospital by car within 30 minutes. However, as has been described in Section 2.1.2, it has been increasingly difficult to find a spot for pregnant women or women already in labour. This is the gap substitutability could potentially fill, as it accounts for the unavailability of the preferred alternative or the nearby hospital. The next section elaborates on factors that are found to be important for pregnant women when deciding on which hospital to go to.

2.3 Hospital decision making

Not surprisingly, when searching for international literature on hospital decision making or bypassing hospitals, most of the literature focuses on rural hospitals. Examples of research come from countries like the United States of America or Australia, where rural hospitals have a lot more difficulties staying financially healthy than urban hospitals (AIHW, 2017; Australian Bureau of Statistics, 2017; Tai, Porell, & Adams, 2004). It is key to view the conclusions in these articles from the perspective of the Netherlands. There are several areas in the Netherlands, for instance the provinces of Drenthe, Friesland and Zeeland, that have a population density of around 200 people per square kilometre. When comparing this to for instance South Holland (1,311/km^2), this is relatively thinly populated (CBS, 2018d). However, when comparing this to Australia's average 3 people per square kilometre, one should question if hospitals in these areas should be marked as rural (The World Bank, 2017).

For this particular study, three databases were searched, namely Google Scholar, Scopus and Science Direct. Only articles published in English were included in the study. Different general search keywords gave the following number of hits, as presented in Table 2.3. As can be seen, more specific searches were required to narrow down the selection of potential literature.

Table 2.3 Number of hits per general search term

Keywords	Google Scholar	Scopus	Science Direct
“Hospital choice”	4140	219	301
“Hospital choice behaviour”	14	5	5
“Hospital choice behavior"	56	5	5
“Choice of hospital”	4880	210	794

It was first decided to include only studies that focused on obstetrics care. As deriving a VoTT is one of the objectives of the SC experiment, a search for existing literature on this specific matter was performed. The used keywords and the number of articles found in the search results are presented in Table 2.4.

Table 2.4 Number of hits per specific search term

Search terms	Google Scholar	Scopus	Science Direct
Obstetrics AND "hospital choice" AND "value of time"	4	0	0
Obstetrics AND "hospital choice" AND "value of travel time"	3	0	0
Obstetrics AND “choice of hospital” AND “value of time”	9	0	1
Obstetrics AND “choice of hospital” AND “value of travel time”	3	0	0
Obstetrics AND “choice of hospital”	916	8	86
Obstetrics AND "value of time"	500	0	744
Obstetrics AND "value of travel time"	28	0	0

For the last three search term combinations, which gave a large number of hits in either Google Scholar or Science Direct, it was needed to further narrow the search. This was mainly done based on judgement of the title of the article, the abstract and the respective journals. Most of the literature found using these terms was on the efficiency of hospitals or efficiency of diagnosis or treatment rather than on hospital choice by patients. Therefore, it was decided to apply the forward snowballing method to the results found by the first two search term combinations of Table 2.4. The different paths taken in snowballing towards the final 30 included articles can be viewed in Table 2.5. The articles marked bold were found using the original search terms from Table 2.4.

Table 2.5 Snowball method paths for literature study

Article	Articles found by forward snowball method
Premkumar, Jones, & Orazem (2016)	Lin, Allan and Penning (2002)
He (2011)	Jintanakul and Otto (2009) Bronstein and Morrisey (1991) Bronstein and Morrisey (1990) Tai et al. (2004)
Gourevitch et al. (2017)	Maurer et al. (2016) Masnick et al. (2016) Faber, Bosch, Wollersheim, Leatherman and Grol (2009)
Victoor, Delnoij, Friele and Rademakers (2012)	Lux et al. (2011) Varkevisser, Van der Geest and Schut (2009) Kolstad and Chernew (2009) Roh, Lee and Fottler (2008)
Lin et al. (2002)	Mayer (1983)
Jintanakul and Otto (2009)	Morgan, Turner and Savitz (1999) Radcliff, Brasure, Moscovice and Stensland (2003) Adams, Houchens, Wright and Robbins (1991) Liu, Bellamy and McCormick (2007)
Bronstein and Morrisey (1991)	Taylor, Zweig, Williamson, Lawhorne and Wright (1989)
Morgan et al. (1999)	Marshall, Javalgi and Gombeski (1995) Lane & Lindquist (1988) Nesbitt, Connell, Hart and Rosenblatt (1990) Savitz, Ricketts and Gesler (1994)
Kolstad and Chernew (2009)	Burns and Wholey (1992)
Liu et al. (2007)	Basu and Cooper (2005)
Tai et al. (2004)	Phibbs et al. (1993)
Varkevisser et al. (2009)	Varkevisser and Van der Geest (2007)

Morgan, Turner and Savitz (1999) provided a short literature review of the factors that influence obstetrics care decision making. This study is centred around studies from the United States and there is no similar recent work that focuses on obstetrics care. The snowball method did however provide a few more studies that reaffirm the study. A number of articles focused on the difference between Medicaid and private insurances and the difference between private and public hospitals in the USA (e.g. Gaskin, Hadley, & Freeman, 2001; Norton & Staiger, 1994). These are left out of this study as everyone in the Netherlands is obliged to have a basic health insurance. Therefore, these effects are less relevant in the Netherlands.

The results found for (acute) obstetrics care specifically were very limited. Despite the fact that Mayer (1983) found that distance behaviour varies with specific diagnoses, it was decided to take a broader perspective by including hospital choice by women in general. The distinction between hospital characteristics and patient characteristics, as used by Morgan et al. (1999), forms the base for the literature study. An overview of the findings by the other studies that either confirm their findings or provide additional factors is given in the next two tables. The review of the patient characteristics is summarised in Table 2.6. The hospital characteristics that are found to be important to patients when choosing a hospital, are found in Table 2.7.

Table 2.6 Literature review on patient characteristics that influence hospital choice

Patient characteristic	Results for women	Results for obstetrics care specifically
Age	Older patients prefer close-by hospitals (Adams et al., 1991; Basu & Cooper, 2005; Buczko, 1992; Radcliff et al., 2003)	Younger women more often deliver in the close-by hospital (Taylor et al., 1989) Older women travel further for care (Bronstein & Morrisey, 1990).
Income	Higher income women are more likely to bypass the closest hospital (Bronstein & Morrisey, 1990; Liu et al., 2007)	
(Complexity of) diagnosis	Women are more likely to bypass local rural hospitals to seek care for more complex services (Adams et al., 1991; Basu & Cooper, 2005; Bronstein & Morrisey, 1991; Morgan et al., 1999)	Women are more likely to bypass the closest hospital if they expect complications in their pregnancy (Bronstein & Morrisey, 1991; Morgan et al., 1999; Phibbs et al., 1993)
Education	Highly educated women are more likely to bypass the closest hospital (Adams et al., 1991; Tai et al., 2004)	Undereducated women are more likely to deliver in the close-by hospital (Taylor et al., 1989)
Area of residence		Women in rural areas with few obstetrical facilities are less likely to deliver in a local hospital, but this can mainly be explained by complications (Morgan et al., 1999)
Employment	Employed women are more likely to bypass the hospital closest to home than unemployed women (Savitz et al., 1994)	

Table 2.7 Literature review on hospital characteristics that influence hospital choice

Hospital characteristic	Results for women	Results for obstetrics care specifically
Size of hospital (number of beds)	Women prefer hospitals with more beds (Adams et al., 1991; Tai et al., 2004)	Number of hospital beds has no statistically significant effect on bypassing odds for women choosing an obstetric hospital (Bronstein & Morrisey, 1991; Roh et al., 2008)
Size of hospital (number of types of services)	Women prefer hospitals with more extensive service capacity (Tai et al., 2004)	The number of health care services provided by a hospital is important to women seeking obstetrics care (Roh et al., 2008)
Academic hospital	Women prefer a university medical hospital (Lux et al., 2011; Varkevisser et al., 2009) Women do not prefer a university medical hospital (Varkevisser & Van der Geest, 2007)	
Word of mouth	Women view experiences by family or friends as an important source of information in obstetrics care decision making (Gourevitch et al., 2017; Maurer et al., 2016)	For obstetrics patients, recommendations from family and friends play an important role in choice of hospital (Lux et al., 2011)
Quality of care	The perception of hospital quality is the most important factor in hospital selection (Lane & Lindquist, 1988)	Few women seek quality information in the process of selecting an obstetrics hospital (Faber et al., 2009; Gourevitch et al., 2017; Masnick et al., 2016)
Satisfaction about local hospital (familiarity)	Women tend to prefer their local hospital if they are satisfied about this hospital (He, 2011; Liu et al., 2007; Tai et al., 2004; Victoor et al., 2012)	In obstetrics care, familiarity with a hospital and feeling connected to this hospital is important to women (Lux et al., 2011; Marshall et al., 1995)

Generally speaking, besides the findings presented in the tables, the distance and the related travel time to a hospital is found to have a strong influence when a woman chooses a hospital in many studies (for example Bronstein & Morrisey, 1990, 1991; Liu et al., 2007; Marshall et al., 1995; Morgan et al., 1999; Tai et al., 2004). This is in line with the expectations. It should be noted that the majority of studies was performed in the United States and these mostly focused on health care accessibility in rural areas. However, it can still be concluded travel time plays a very important role in obstetrics care decision making.

The literature study shows there is large added value in conducting a SC experiment focused on obstetrics care decision making in the Netherlands. The value of time for traveling for obstetrics care has not yet been identified in monetary terms in the existing literature. The next section discusses the conclusions that have been drawn based on the performed literature studies.

2.4 Conclusion

The purpose of this chapter and its subsequent sections was to provide a (partial) answer to the first two sub-questions by means of literature studies. It should be noted that the results of these literature studies are prone to subjectivity. The scanning and evaluation of article titles and the different journals these studies were published in have played a major role in whether or not to include a study in the review. These decisions are based on the researcher's judgement.

Section 2.1 and 2.2 help answer the first sub-question: *What does the current acute obstetrics care system of the Netherlands look like, and how has its spatial distribution developed over the last decade?* The literature review showed that based on the used accessibility performance indicators, the AO care distribution has scored relatively well over the last decade. Several developments have however forced RIVM to optimize the ambulance distribution, and in the last few years, representatives of several AO locations have expressed worries about the situation. These worries have to do with the long ambulance trip times in some locations. Furthermore, and maybe even more remarkable, the difficulties of finding personnel and the pressure on current personnel have led to unavailability of beds and being forced to say 'no' to women in labour. These developments make it questionable whether the accessibility and spatial distribution measures in place accurately capture the performance of the system. A woman in search for an available bed to deliver in, is not as a matter of course helped by a single hospital in vicinity of her place of residence.

The base for the answer to sub-question two is formed in Section 2.3. The question reads *Which factors influence the decision for women in the Netherlands when choosing a hospital for acute obstetrics care, and to what extent?* The literature review helped identifying a list of hospital related factors that are usually considered when choosing a hospital for different purposes as presented below.

- Costs of care
- Quality of care
- Size of hospital in terms of care units
- Size of hospital in terms of number of beds
- Available facilities
- Influence on decisions to be made
- Travel time to hospital
- Word of mouth / recommendations
- Satisfaction about a hospital / familiarity

The next chapter will help sharpen the answer to this sub-question by means of a SC experiment among women in the Netherlands. The input of the literature review are used as the base for the survey.

3 Stated choice experiment

The substitutability model requires travel time and travel cost parameters, so the objective of this chapter is to identify parameters for travel costs and travel time. As the concept of VoTT is very well-researched, one could base these parameters for travel costs and travel time based on literature (Mouter & Chorus, 2016). However, traveling to a hospital is an oftentimes uncommon activity. In this specific case, a SC experiment is a suitable method to identify the VoTT for women when choosing an obstetrics care location. This chapter will elaborate on the theoretical background of SC experiments, on the different characteristics of this research method and on the different steps taken to arrive at the final survey. Afterwards, the results of the conducted survey are discussed, which will serve as input for the discrete choice model.

The use of questionnaires is viewed as a fairly time-efficient means of gathering data on a large scale as they can be sent to a great number of people simultaneously. By using closed-ended, structured questions, the intention is to collected identical data that is rather easy to analyse (see amongst others Brown, 2001; Gillham, 2008; Lynch, 1996; Robinson, 1991; Seliger & Shohamy, 1989; Zohrabi, 2013). However, response rates may be very low, especially when sent via email or posted online. Another disadvantage is that, when a respondent does not understand a question, there is no way this person can ask for help from the research. Ambiguity of questions can also lead to inaccurate responses (Brown, 2001; Gillham, 2008; Zohrabi, 2013). Concludingly, whenever using questionnaires as a research method, it is very important to determine the goal, the audience and the desired number of respondents. Also, it is crucial to pilot the designed questionnaire on a potential respondent before sending out the survey (Blaxter, Hughes, & Tight, 2010).

The next section will shortly elaborate on the theoretical background of SC experiments. Afterwards, Section 3.2 describes the survey requirements. In Section 3.3, the construction of the SC experiment is explained and Section 3.4 presents the results and discussion. Finally, Section 3.5 concludes the chapter by answering the second sub-question.

3.1 Theoretical background on SC experiments

When conducting a SC experiment, one assumes the respondent has a free choice when selecting a hospital to go to. Essentially this is the case in the Netherlands:

> "From previous research it follows that, in the Netherlands, the decision of which hospital to visit is most often made by patients themselves, alone or in consultation with their general practitioner. Since Dutch general practitioners do not face economic incentives to refer patients to particular hospitals, it is not in their interest to neglect patients' interests when deciding which hospital they should visit."
>
> Varkevisser & Van der Geest, 2007, p. 289

Therefore, the idea is to design a simple SC experiment to derive the VoTT for women when they decide on an obstetrics location. As SC experiments are quite complicated by nature, keeping it relatively short is important in order to ensure unambiguity and prevent respondent-fatigue.

SC experiments for travel behaviour research can roughly be divided into two subcategories, conjoint analysis and discrete choice analysis. The former is based on the ranking of alternatives. This approach allows a researcher to examine the attractiveness of particular attributes of different alternatives. In other words, conjoint analysis offers insights in consumer preferences (Louviere, 1988). When a researcher wants to take the next step and predict consumer choices based on economic theory, discrete choice analysis can be used (Adamowicz, Louviere, & Swait, 1998). Discrete choice analysis requires a respondent to choose between presented alternatives. This allows for determination of the impact of attributes on alternative utility, like travel cost and travel time (Kroes & Sheldon, 1988). From a respondent perspective, it is also easier to pick one alternative than to rank several alternatives. This makes discrete choice analysis more suitable for behaviour analysis (Molin, 2016b). Discrete choice modelling is therefore used to predict the VoTT for women choosing obstetrics care. The details on discrete choice analysis will be discussed in Section 3.4.3.

A SC experiment consists of a certain number of choice sets. A choice set includes one or more alternatives or options. These alternatives have two or more attributes. Every attribute has two or more levels. Based on the number of attributes and the appurtenant attribute levels, the minimum number of choice sets to be presented to every respondent can be defined. This is based on the experimental design, which is elaborated on in Section 3.3.2. The next section first discusses the requirements of the survey.

3.2 Survey requirements

First of all, it is important to make sure it is easy for the respondent to fill in the survey. Google Forms is used, as it provides a very user-friendly interface. Furthermore, it allows respondents to fill in the survey on any mobile device. It also offers the researcher the possibility to export obtained data to a spreadsheet.

Secondly, the survey should be understandable for the respondent. Female residents of the Netherlands form the target audience. As it is likely the majority of women are not familiar with SC experiments, it is necessary to include explanation on what is expected from the respondent and to demonstrate this using an example. Furthermore, as the focus is on women in the Netherlands, the survey is constructed in Dutch.

It is also important to keep assumptions about the alternatives to a minimum. These assumptions could lead to uncaptured effects. This means all relevant factors need to be included in the SC experiment. However, the literature review as presented in Chapter 2, shows little consensus on relative importance of hospital and patient characteristics for patients' choice of hospital. Different research projects found different factors to be the most important to patients. The main objective of this SC experiment is to derive travel cost and travel time parameters. To minimize the effect of assumptions made by the respondent, it is not necessary to include all potentially relevant parameters as attributes. Naming factors like 'quality of health care', 'costs reimbursed by health insurance' and 'health care facilities' as context settings works as well. In the explanation page of the online survey, the respondent is asked to consider the factors that are not explicitly mentioned to be equal between the different alternatives. The factors that appear in this list are based on the literature review and on comments by three potential respondents that were asked to give feedback on the initial survey. The entire description attached to the survey can be found in Appendix A. The appendix contains the original version in Dutch. This concludes the first part of the survey.

The second part of the survey contains the SC experiments. The respondent is asked to choose between the alternatives. It is possible to include a base-alternative ('I prefer not to use any of these options'). If a respondent chooses the base-alternative, this choice set provides no information on trade-offs among attributes (Molin, 2016b). An example of research where including a base-alternatives is relevant is when studying whether or not people would make use of automated vehicles. As conventional cars are the current standard, some respondents might be reluctant to ever switch to automated vehicles, as it is something they are not used to. If one would in this case leave out a base-alternative that allows a respondent to choose the conventional car alternative, model estimations would be unreliable (De Looff, 2017; Molin, 2016b). However, as a respondent for this research has to pick a hospital, and it is only provided with information that is in the choice set, the inclusion of a base alternative is not necessary. So, the choice sets will only include alternatives that have specific attributes and levels. The steps taken in the choice set design process are presented in Section 3.3.

The third and last part of the survey contains questions related to the respondents' socio-demographic characteristics. Furthermore, several questions have been included regarding pregnancy. However, these are non-required questions as they are quite personal, and a woman may not be comfortable with sharing this information. All questions can be found in Table 3.1. The answers to these questions will guide validation of the representativeness of the sample.

Table 3.1 General questions included in the survey and the appurtenant variables

Question	Answer	Socio-demographic variable	Categories
How old are you?	… years old	Age class	<21 21-25 26-30 31-35 36-40 41-45 46-50 >50
Have you been to a hospital in the previous year?	Yes, No, RNA	Recent hospital visit	Yes No
Have you ever given birth?	Yes, No, RNA	Delivery	Yes No
At which location was your last delivery?	At home, In an obstetrics clinic, At a hospital, RNA	Delivery Location	At home In an obstetrics clinic At a hospital Other
What is your highest level of education?	Primary school, Secondary school: MAVO/VMBO, Secondary school: HAVO/VWO, MBO, HBO, WO	Education level	Low Intermediate High
How would you describe your daily participation?	I work full-time, I work part-time, Student, Retired, Currently unemployed	Occupation	I work full-time I work part-time Student Retired Unemployed / other
What is your yearly net-income?	<€10,000, €10,001-€20,000, €20,001-€30,000, €30,001-€40,000, €40,001-€50,000, >€50,001	Net income class	<€10,000 €10,001-€20,000 €20,001-€30,000 €30,001-€40,000 €40,001-€50,000 >€50,001
Do you own a car?	Yes, No	Car ownership	Yes No
What are the four digits of your zip code?	_ _ _ _	NA	NA
			RNA = I prefer not to answer this question

3.3 Design of the choice sets

This section will discuss the different aspects of designing SC experiments. The environmental context of the choice sets has already been discussed in the general description of the survey. The respondent has been asked to consider all other factors to be equal between the different alternatives. This section first discusses attributes and their subsequent levels. Then it zooms in on the different types of experimental designs that are considered, and which will be used.

The number of alternatives in each choice set is set to two. This is sufficient to get valid results, and it is easier for respondents to choose between two rather than three alternatives. The next section discusses the different attributes and levels. The alternatives are presented in a graphic that is easily readable from both mobile as well as computer devices. The theme colour is blue, in order to avoid any assumption on which alternative is better than the other, which may happen when choosing green or red as a base colour. The attributes and levels are explained in detail in the next section.

3.3.1 Attributes and levels

To objective of this SC experiment is to get an insight in the relative importance of travel time to a hospital in the case of AO decision making. To estimate a time parameter, it needs to be compared to other relevant factors. As a VoTT is estimated based on travel time and travel costs, at least these two attributes had to be included. To make the experiment feel more realistic, another attribute is added, namely 'Recommendation' or 'Aangeraden' in Dutch. All three attributes and the appurtenant levels will briefly be discussed.

- Travel time

Travel time is expected to have the most impact on decision making for obstetrics care in this SC experiment. Even if there are no complications during pregnancy, and the woman prefers to deliver at home, it is possible she needs to be taken to a hospital for the actual delivery. For the woman and potential visitors, it is convenient if a hospital is easy to reach. Consequently, a hospital that is close-by is expected to be strongly preferred. The decision on the range of travel times to be included in the experiment is made based on the travel times to AO locations as documented by RIVM (RIVM, 2018a). The vast majority of the country can reach an AO location within 30 minutes. Furthermore, when focusing on women in the fertile age range from 15 to 45 year, 99.7% of all residents can reach an AO location by car within 30 minutes (RIVM, 2018a). Therefore, the maximum travel time to be included in the SC experiment is set to 30. In order to make it possible to test for linearity, at least three levels are required. Based on equidistance, the following three levels are included:

Travel time (minutes): 10, 20, 30.

The parameter value is expected to be negative, as a longer travel time is predicted to have a negative effect on utility of an alternative. The parameter is expected to be significant and the impact on utility is expected to be the largest of the three parameters. This parameter is from now on referred to as β_{TT} or β_T.

- Travel costs

The travel costs are roughly based on the travel times. Again, three levels are considered to enable linearity calculations if required. Initially, the levels in euros were set to 4.50, 6.00 and 7.50. However, after a discussion with a potential respondent, these levels were re-evaluated. To derive at suitable values, it is important to balance on the one hand realistic scenarios and on the other hand the potential to influence decision making. It was decided to base the maximum travel costs on the maximum travel time. On average, costs for car use per kilometre are about €0.19 per kilometre (ANWB, 2018). It is assumed one can travel about 45 kilometres in 30 minutes, which leads to a cost of €8.50. Ensuring equidistance, the following levels have been chosen.

Travel costs (€): 3.50, 6.00, 8.50.

The travel cost parameter is from now on also referred to as β_{TC} or β_C. It is predicted the travel costs have a negative impact on utility, so the expected sign of the parameter is a minus. However, it is possible the SC experiment results in an insignificant parameter for travel costs. In AO location decision making, it is expected women in the SC experiment find costs a lot less important than travel time.

- Recommendation

The third and last attribute included in the SC experiment is 'recommendation'. Initially, the idea was to include the levels 'yes' and 'no'. However, including these levels implied a risk of non-trading behaviour. Non-trading behaviour occurs when a respondent always chooses an alternative based on one specific attribute and for one specific level, regardless of the other attributes and levels. It is possible a respondent would never choose a 'not-recommended' hospital. Consequently, after re-evaluation, it was decided to use a 5-star scale, and the following levels were included:

Recommendation (out of 5 stars): 2, 3, 4.

The recommendation parameter is from now on also referred to as β_R or β_{RECOM}. It is expected the effect of an extra star is significant and positive. However, the main objective of the SC experiment is to derive accurate travel time and travel costs parameters for women in AO decision making. So, the value for β_R may be neglected in the end. The main objective of the experiment also shapes the experimental design used, which is discussed in the next section.

3.3.2 Experimental design

To maximise the chances of retrieving reliable parameters from a SC experiment, there are several ways the different alternatives and choice sets can be designed. These options are referred to as experimental designs. For this SC experiment, two factors play a major role in the decision on which type of design to use. On one hand, the number of choice sets should not be too large to prevent respondent-fatigue and on the other hand it is important to minimise correlations between alternatives. Zero correlations between attributes lead to smaller standard errors which in turn leads to more reliable parameter estimations. However, it is difficult to avoid multicollinearity and achieve zero correlations between attributes without including a large number of choice sets. Technically speaking, the standard error is an indicator of the reliability of an estimated parameter value (Chorus, 2018). A low standard error leads to higher statistical significance. The mathematical background to this can be found in Appendix B. Three types of experimental designs will now be discussed briefly, namely full factorial, fractional factorial and efficient designs.

Full factorial designs include all possible combinations of attribute levels. The number of alternatives is equal L^N, in which L is the number of levels and N denotes the number of attributes (Molin, 2016a). For the chosen attribute levels, this would lead to 3^3 or 27 alternatives. One could now randomly select a few alternatives to present to the respondents. However, this is very inefficient.

A better option is to use fractional factorial designs. This type of design can be retrieved by hand or by using software, such as Ngene (ChoiceMetrics, 2018). The use of basic plans enables a researcher to select an orthogonal fraction by hand (Addelman, 1962). Orthogonality means the correlations between attributes are equal to zero, which increases efficiency when estimating models. Some orthogonal designs also reach attribute level balance. This means all attribute levels are used an equal number of times in the alternatives. Attribute level balance is a desirable characteristic, as it results in equal standard errors for every parameter. However, attribute level balance is not required as it does not affect the validity of the estimated parameters. An advantage of fractional factorial designs is orthogonality. However, it is possible the number of alternatives gets very high, which is undesirable from the perspective of the respondent.

The last and third type of designs is efficient designs. The major advantage of efficient designs is that the alternatives are constructed in a way that minimizes the number of respondents needed to obtain significant parameters. A disadvantage of efficient designs is that they are dependent on priors. Priors are estimates of the parameters used in the model. If the wrong priors are used, the design would be inefficient which may result in unreliable parameters. There are two well-known ways to get priors. Priors can be based on existing literature. Secondly, priors can be calculated by distributing a pilot among about 30 respondents (Molin, 2016c). The latter method is used in this research. The different steps taken to get the priors are described in Appendix C.

Ngene accommodates various types of efficient designs, dependent on the discrete choice model the researcher is planning to use later on. In this research, the Multi Nominal Logit (MNL) Bayesian Mean D-efficient design is used. This design accounts for uncertainty of parameters and at the same time creates an efficient design (Aloef, 2015). As there existed uncertainty about the travel cost prior value, this design was used. For an in-detail description of how it was applied, see Appendix C. Coherent to the decision on which type of design to use, comes the decision on the method of choice set construction. This is briefly elaborated on in the next section.

3.3.3 Choice set construction

There are two well-known ways to construct a choice set. The first method is sequential construction. This method is generally used when all alternatives have the same attributes and levels and unlabelled alternatives are used (Molin, 2016b). Unlabelled alternatives refer to alternatives that have names that do not represent a characteristic (Bliemer, Rose, & Chorus, 2017). An example of labelled alternatives is a choice set that contains a “car” option and a “bike” option.

After the creation of all alternatives, the researcher decides how many options should be in each choice set. If this is two, one makes two piles that both include all alternatives and a choice set is created by randomly drawing one alternative from a pile. A redraw happens when two draws give the same alternative or when a choice set is replicated (Molin, 2016b). Sequential construction will lead to correlations between alternatives. This does not have to be problematic, but low correlations are preferred as it minimizes standard errors (see Appendix B). It is possible to reduce correlations by endless random drawing. However, usually correlations between attributes are not too problematic when using unlabelled alternatives (Molin, 2016b).

The second choice set construction method is the simultaneous method. Contrary to sequential construction, this method is usually preferred when using labelled alternatives. This way, when using Ngene for example, a row of a design constructs two alternatives simultaneously and represents a choice set. This way, the correlations between alternatives are equal to zero. A disadvantage is that oftentimes, more choice sets are needed (Molin, 2016b). In this research, for the pilot design, the sequential method is chosens as unlabelled alternatives are used. For the application, see Appendix C. The next section contains a summary of this appendix and presents the final SC experiment details.

3.3.4 The final SC experiment

Using an orthogonal sequential design, the pilot survey was constructed. This helped in testing the understandability of the description added to the survey and enabled the estimation of prior values. 33 relatives filled out the pilot survey. The description was reshaped a bit after some comments. As β_{TC} was insignificant on a 99% confidence level, it was decided to use a Bayesian mean D-efficient design for this parameter. See Appendix C for an extensive description of the process.

The final 9-row design included three dominant alternatives. Two of these choice sets were deleted and one was kept and added as a last choice set. Keeping it as the second question could have led to respondents questioning the quality of the survey and eventually dropping out. It is safer to add a dominant alternative as the last question. The dominant choice set will be used as a check to see if every respondent fully understood the SC experiment. Concludingly, the following seven choice sets are used for the final survey, as presented in Table 3.2.

Table 3.2 Choice sets used in the final survey

Choice situation	alt1.time	alt1.costs	alt1.recom	alt2.time	alt2.costs	alt2.recom
1	10	3.5	2	30	8.5	3
2	20	3.5	3	10	6	3
3	10	6	3	20	6	4
4	20	6	4	30	3.5	4
5	10	8.5	4	30	6	2
6	30	3.5	4	20	8.5	2
7	30	6	2	10	3.5	2

The final survey had the following outline:

- Description on the survey and on the SC experiment in particular (Appendix A),
- the SC experiment (7 choice sets of 2 alternatives each),
- and the general demographic questions (either 8 or 9 questions, dependent on answers).

The latter two can be found in Appendix D. The next section will elaborate on the results of the survey.

3.4 Results and discussion

As the outcomes of the survey are used for the substitutability calculations for AO locations in the Netherlands, only Dutch females were eligible for the survey. The final survey was filled out by 155 people. The sample is drawn using the non-probability method of convenience sampling. Using online tools such as personal email and Facebook distribution, people who are easy to reach filled out the survey (Etikan, Musa, & Alkassim, 2016). As several closely related people further distributed the survey using their personal networks, the snowball method helped gathering respondents (Goodman, 1961). All responses were gathered within a time span of 16 days, from 29 March to 14 April 2019. The response rate of the people approached using personal email is unknown, as the respondents were not asked how they came across the survey.

The fact that a non-probability sampling method was used does not directly imply the sample is not representative for the population (Yeager et al., 2011). The representativeness will be elaborated on in Section 3.4.2. However, the data of the SC experiment first need to be prepared for analysis. This section therefore first discusses the data preparation steps taken. Section 3.4.2 then zooms in on the sample characteristics. This will give more information on to what extent the sample was representative for the population. In Section 3.4.3, a model estimation will be presented. The last section contains a discussion and presents the limitations of the SC experiment and its outcomes.

3.4.1 Data preparation

Before all else, all men were removed from the dataset, bringing the total responses to 151. All female respondents fully completed the survey. The Google Forms output was exported in a spreadsheet. The collected data of the 155 responses are prepared for analysis using R. The most important steps will be described in this section. To start with, the SC data is processed. The script used is Script 5, which can be found in Appendix E. It was first checked whether respondents had chosen solely hospital A or hospital B. This could imply respondents did not fill in the survey honestly and with attention. This was not the case, so no removal happened in this stage. All SC preferences of the 151 respondents can be found in Figure 3.1.

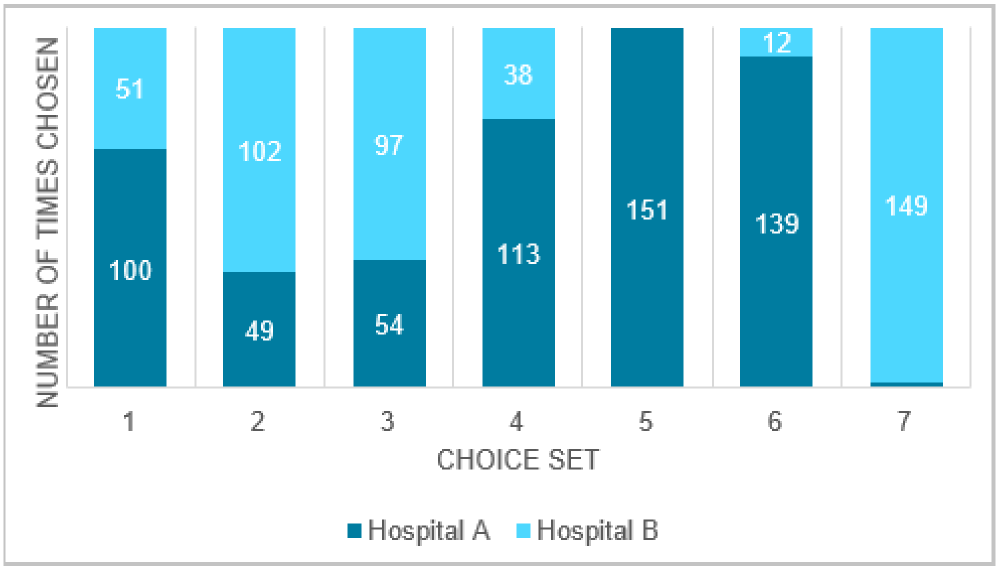


Figure 3.1 The 151 SC responses of the final survey (after deletion of male respondents)

Next, a dominance check was performed. As described in Section 3.3.4, one of the choice sets contained a dominant alternative. However, when checking for dominance, the replies for this choice set showed two erroneous choices. It was assumed these respondents either did not fully understand the SC experiment or did not carefully read the seven choice sets. Therefore, all replies by these respondents were removed from the data, bringing the total number of respondents to 149. The dominance check revealed dominance in another choice set, as can be seen in Figure 3.1. For choice set 5, all respondents chose Hospital A. Choice set 5 is given in Figure 3.2. Apparently, the very low recommendation rating and the very long travel time to hospital B made all respondents choose Hospital A, despite the slightly lower travel costs of Hospital B. While the second alternative was not strictly dominant (see Appendix C for an in-detail explanation on dominance), it turned out to be dominant to the sample. The replies to the choice set will still be kept in the dataset.

Figure 3.2 Choice set 5, in which Hospital A was dominant

This brings the total number of completely filled-out and usable surveys to 149. The number of observations is therefore equal to 745. The next section will discuss the sample characteristics and the representativeness of the group of respondents.

3.4.2 Sample characteristics and representativeness

This section will elaborate on the demographic characteristics of the 149 respondents in the final data set. Of the 149 responses, two four-digit zip codes were not filled out correctly. Furthermore, some people did not provide all information regarding hospital visits and net income. However, all available data are used for the evaluation of the representativeness of the sample. It is expected the sample will not be representative for women in the Netherlands, due to the distribution methods used. Most probably, highly educated women will be overrepresented in the sample. Furthermore, it is expected that respondents from remote areas will be underrepresented. These expectations arise because the survey was distributed using Facebook and personal emails. With the use of Excel and data provided by CBS Statline, it is possible to compare the sample to the population. A summary of data that is publicly available and can therefore be compared to the survey statistics is given in Table 3.3. The year reported for each variable represents the year the latest statistics for the female population of the Netherlands were available.

The age categories show the age group between 21-25 years is overrepresented as well as, to a smaller extent, the 41-45 years category (CBS, 2018b). This is in line with expectations. The age categories are chosen this way because they represent the fertile age of women according to CBS (2019). The age category 15-20 is left out of this research due to underrepresentation, as the youngest respondent was 19 years old.

The last delivery location of the 99 respondents that had ever given birth is fairly similar to the population (Perined, 2017). The number of at home deliveries is a little overrepresented. However, this can be explained by the fact that the majority of respondents that reported to have ever given birth were over 40 years old. This implies they have probably given birth 10 to 20 years ago. A little over a decade ago, 23% of all deliveries in the Netherlands happened at home (Stichting Perinatale Registratie Nederland, 2005).

The education levels have also been adapted using the definition of CBS. Low education includes primary school, pre-vocational education (MAVO, VMBO) and vocational education to the entry level. Intermediate education comprehends general secondary education (HAVO, VWO) and vocational education (MBO). The high education contains all education at tertiary level, such as for example academic bachelors and masters (HBO, WO) (CBS, 2019a). The number of highly educated respondents is a lot higher than the population statistics (CBS, 2019c). Consequently, the sample is not representative on the base of education level. The overrepresentation of highly educated women in the sample can be explained by the way of recruiting respondents, mainly based on the personal network of the author.

The sample distributions based on employment show an overrepresentation of working women and students compared to the population (CBS, 2015a, 2018c, 2018b). This can be explained by the high education level of the sample and the large number of respondents in the aged 21-25.

The different income classes in the sample are fairly comparable to the population (CBS, 2019b). The sample contains a relatively high number of people in the lowest income class. However, the vast majority (29 out of 31) of the respondents in this class are students. The overrepresentation of the highest income class can most probably be explained by the high education levels and the number of respondents that is over 40 years of age. Furthermore, it is possible people assumed the income question to refer to the net income of their household instead of their personal net income.

The numbers for car ownership of the female population in the Netherlands are outdated and the actual numbers are expected to be higher at this point in time (CBS, 2015b). Furthermore, it is possible respondents understood the question as whether or not they have a car available, instead of car ownership. The skewness of the comparison is therefore neglected.

Table 3.3 Comparison survey sample and population on demographics

Variable	Range	Sample	Population	Difference (point)
Age class (2018)	<21	2.0%	21.5%	-19.5%
	21-25	22.5%	6.1%	16.4%
	26-30	4.6%	6.3%	-1.7%
	31-35	3.3%	6.0%	-2.7%
	36-40	6.0%	5.9%	0.0%
	41-45	18.5%	6.0%	12.5%
	46-50	11.3%	7.3%	3.9%
	>50	31.8%	40.8%	-9.0%
Delivery location (2017)	At home	27.3%	12.7%	14.6%
	In a hospital	68.7%	71.5%	-2.8%
	Clinic	1.0%	15.1%	-14.1%
	Other/unknown	3.0%	0.7%	2.3%
Education (2018)	Low	0.7%	29.5%	-28.8%
	Intermediate	19.2%	39.0%	-19.8%
	High	80.1%	31.6%	48.6%
Occupation (2017, 2018)	Full-time work	31.3%	12.6%	18.7%
	Part-time work	41.3%	35.2%	6.1%
	Student	20.7%	7.1%	13.6%
	Retired	1.3%	19.7%	-18.4%
	Other	5.3%	25.4%	-20.1%
Net income class (2017)	Less than €10,000	24.4%	18.4%	6.0%
	€10,001 - €20,000	11.8%	35.0%	-23.2%
	€20,001 - €30,000	22.0%	19.8%	2.2%
	€30,001 - €40,000	15.0%	12.3%	2.7%
	€40,001 - €50,000	8.7%	6.6%	2.1%
	More than €50,001	18.1%	7.9%	10.2%
Car ownership (2015)	Yes	73%	37%	36%
	No	27.2%	63.1%	-35.9%

Besides the general personal questions, the respondents were also asked to fill in their four-digit zip code. Two respondents did not complete this question. The geographical distribution of the remaining respondents is shown in Figure 3.3 which is created using BatchGeo ("BatchGeo," 2019). The only conclusion to be drawn from this map is that the most northern and southern regions are underrepresented in the sample.

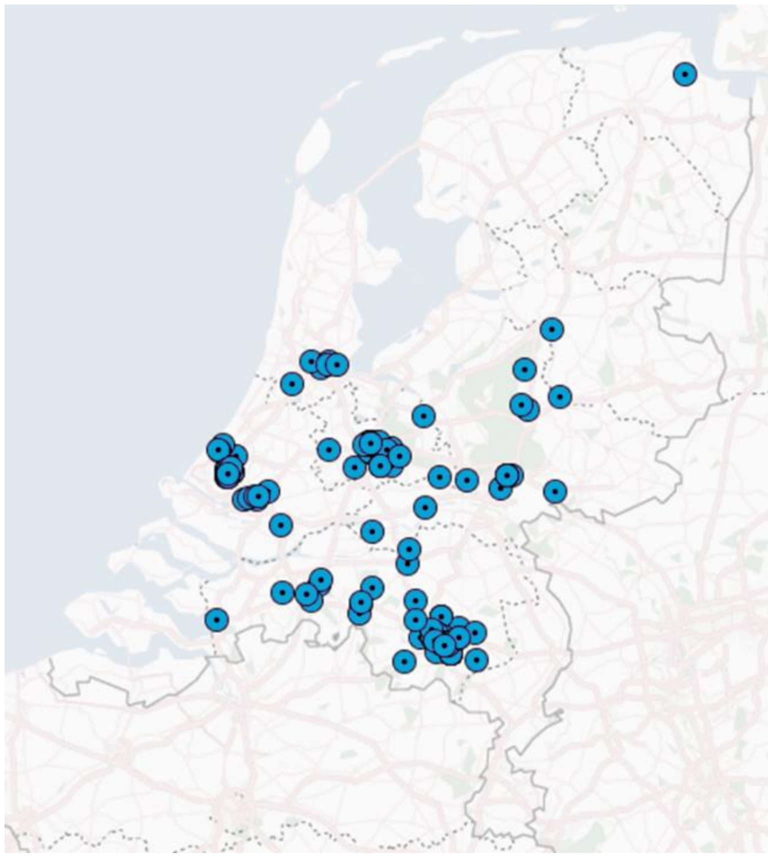


Figure 3.3 Geographical locations of residency of all respondents (Source: BatchGeo)

By means of the measure of urbanity, as indexed by CBS, it is possible to divide the municipalities of the Netherlands into five categories from rural to extremely urbanised (CBS, 2018d). The obtained zip codes have been linked to the list of municipalities and this results in the distribution of the sample in these five categories. Combined with the number of female residents of each municipality, the distribution for the population can be calculated as reported in Table 3.4.

As can be seen, no respondents live in rural or not urban areas. Moreover, the 'very urban' category is underrepresented while 'extremely urban' is overrepresented. When one would combine these categories, the share of sample (55%) and share of population (54.7%) would be approximately equal in size. The major problem therefore lies within the lack of respondents from rural areas, which maybe even is the most important target group when focusing on spatial distribution of AO locations. This subject and other limitations of the survey are discussed in Section 3.4.4.

Table 3.4 Sample and population compared on extent of urbanization

	Survey	Survey share	Population	Population share	Difference (point)
Rural	0	0.0%	681,754	7.9%	-7.9%
Little urban	26	17.4%	1,862,057	21.5%	-4.1%
Moderately urban	41	27.5%	1,381,091	16.0%	11.6%
Very urban	27	18.1%	2,644,389	30.6%	-12.4%
Extremely urban	55	36.9%	2,084,752	24.1%	12.8%
Total	**149**	**100%**	**8,654,043**	**100%**	

3.4.3 Model estimation

There are several discrete choice models a researcher can use. The most well-known model families are the traditional Random Utility Maximization (RUM) model family as introduced by McFadden in 1974 and the Random Regret Minimization (RRM) models. Both are based on fundamentally different assumptions. The most-commonly applied methods come from the RUM family. The base model is the MNL model. Several extensions have been added to overcome the limitations of the MNL model, such as the Nested Logit (NL), Mixed Logit (ML), and Latent Class (LC) models. For an overview of different types of discrete choice models and their main characteristics, see for instance Ben-Akiva et al. (2002) and McFadden & Train (2000). For a detailed discussion of the underlying assumptions of RUM and RRM models see for example Chorus (2012).

The decision on which model to use strongly depends on the objective of the research or the research questions. The SC experiment has been executed with the aim to identify a VoTT for female inhabitants of the Netherlands when choosing a hospital with AO facilities. Therefore, a RUM-MNL model is used. It is assumed that respondents chose the alternative from which they derived the most utility (RUM assumption) rather than from which they derived the least regret (RRM assumption). Furthermore, the MNL model is suitable for the derivation of the VoTT and can easily be applied when the dependent variable is unordered like the decision on a hospital to visit (Chorus, 2018).

For the substitutability calculations, the outcomes of the MNL model estimations are used. The outcomes of the PythonBiogeme model estimations are presented in Table 3.5.

Table 3.5 Estimation report MNL model

Name	Value	Std err	t-test	p-value
β_R	1.6	0.141	11.39	0.00
β_{TC}	-0.0683	0.0261	-2.62	0.01
β_{TT}	-0.0924	0.00935	-9.88	0.00
Number of estimated parameters:				3
Sample size:				894
Excluded observations:				0
Init log likelihood:				-619.674
Final log likelihood:				-416.458
Likelihood ratio test for the initial model:				406.431
Rho-square for the initial model:				0.328

All three βs are of the expected sign as elaborated on in Section 3.3.

To get an insight in the effects of the different parameters on the utility functions the parameter values are multiplied by the attribute level range.

$$\beta_R * (\max_R - \min_R) = 1.6 * (4 - 2) = +3.2$$
$$\beta_{TC} * (\max_{TC} - \min_{TC}) = -0.0683 * (8.50 - 3.50) = -0.3415$$
$$\beta_{TT} * (\max_{TT} - \min_{TT}) = -0.0924 * (30 - 10) = -1.848$$

In contrast to the pilot outcomes, the utility effect of β_R is now the largest of all three parameters. This goes against the expectations of the importance of the travel time. As expected, the impact of β_{TC} is smallest. Apparently, travel costs are relatively unimportant to women who choose a hospital for AO care. The standard errors of all three parameters are sufficiently small, which implies significance of all three parameters.

The exploratory power of a model can be assessed by the likelihood ratio statistic (LRS) as reported in Table 3.5 as well. The LRS tests whether the estimated model is the statistically 'better' model than the null model. The LRS is chi-square distributed, based on the number of parameters k used and the critical value p: $\chi^2(p,k)$. The LRS can be calculated using equation (1). A model fits the data statistically better when $LRS > \chi^2(p,k)$ (Van Cranenburgh, 2016).

$$LRS = -2\ (LL_{null} - LL_{MNL}) \tag{1}$$

The critical χ^2 value for three parameters and p = 0.01 is 11.341 (Wilson & Hilferty, 1931). Using (1), the following value for LRS is found.

$$LRS = -2\ (-619.674 - -416.458) = 406.431$$

As $LRS > \chi^2(p,k)$ or $406.431 > 11.341$, it is concluded the estimated model fits the data significantly better than no model. Using the parameter values as presented in Table 3.5, the following model for the utility of alternatives is created:

$$V_i = recom_i * \beta_R + travel\,cost_i * \beta_{TC} + travel\,time_i * \ \beta_{TT}$$

$$V_i = R_i * 1.6 + TC_i * -0.0683 + TT_i * -0.0924$$

The VoTT is a central element in the substitutability model. Therefore, it is assumed both β_{TC} and β_{TT} are linear. Consequently, the VoTT can be calculated using equation (2). Note that this value for VoTT is in euro/min, so it will need to be multiplied by 60 to retrieve the more commonly reported €/hour value.

$$VoTT = \frac{\beta_{TT}}{\beta_{TC}} = \frac{\left[\frac{util}{min}\right]}{\left[\frac{util}{euro}\right]} = \left[\frac{euro}{min}\right] \tag{2}$$

The VoTT for the sample is therefore equal to 81.71 €/hour:

$$VoTT\ \left[\frac{€}{\text{hour}}\right] = \frac{-0.0924}{-0.0683} * 60 = 81.17\ \left[\frac{€}{\text{hour}}\right]$$

This value is extremely high compared to other research literature. For instance, the VoTT used by the Ministry of Infrastructure and Water Management of the Netherlands for non-commute or business travel is equal to 7.50 €/hour (Kouwenhoven et al., 2014). Furthermore, Ramjerdi, Flügel, Samstad and Killi (2010) identified the range of acceptable VoTT based on Norwegian data to be 10.37 - 19.67 €/hour.

However, none of these studies take urgency or acute situations into account. The SC experiment as executed in this research serves as an attempt to fill this gap by capturing both the regular obstetrics care hospital visits as well as an eventual emergency visit. By adding this to the description of the survey, respondents were made aware of this assumption. Therefore, the found high VoTT of 81.17 €/hour is accepted, as travel time is extremely important when it comes to eventual emergency situations. However, the difference between the VoTTs found in other studies and this VoTT is bigger than expected. This and other issues will be discussed in the next section.

3.4.4 Discussion

The previous section presented the results of the SC experiment. These results are discussed in this section. Remarkable parameter outcomes are discussed first. Afterwards, the focus will be on discussion of the model. Finally, some general remarks are made that may affect the ability to draw conclusions from the SC experiment.

- Parameters

First of all, the parameters. The value and the utility effect of $\beta_{recommendation}$ are larger than expected. The expectations for this parameter were based on personal communication with some of the prior estimation study respondents and on the outcomes of the prior estimation study. There is no literature that specifically discusses the effects of recommendations in hospital situations. However, for example Liu, Bellamy and McCormick (2007) and Tai et al. (2004) found significant effects on hospital choice based on the satisfaction about a certain hospital. The effect of satisfaction about a hospital might be comparable to whether a friend had recommended a hospital strongly or this friend was less satisfied. If the magnitude of this effect would have been known beforehand, the outlook of the SC experiment would have been different. The attribute and its levels would have probably been revised and maybe even removed. The fact that this did not come forward in the pilot study may be due to the fact that most of the pilot respondents are relatively young and never had a baby. This may have caused these respondents to care less about recommendations as they may have been more rational when it comes to AO care.

The cost parameter $\beta_{travelcost}$ was of the expected sign and the utility effects were, as expected, the smallest of all three parameters. One of the respondents of the final survey mentioned she thought the prices (in other words, the attribute level range) were way too small and they had absolutely no effect on her decision making. This may have caused the less significant effects of the cost parameter. This could have probably been prevented by using higher prices and a larger price range. However, a side effect of this would have been that it would have made the alternatives and therefore the choice sets a lot less realistic.

The parameter for travel time $\beta_{traveltime}$ was expected to have the highest utility effect. However, it turned out this attribute was less important to the respondents than $\beta_{recommendation}$, relatively seen. This could potentially have been caused by the chosen attribute level range. However, the results also show travel time to be an important factor in AO location decision making. This is in line with literature in other hospital care sectors in both The Netherlands as well as other countries. (Beukers, Kemp, & Varkevisser, 2014; Sivey, 2012; Smith Gooding, 2005). It is nevertheless complicated to assess the correctness of the amplitude of the estimated parameter, due to a lack of research with similar settings. The only factor that can directly be compared to other studies is the found VoTT.

The VoTT found for this sample study is very high. As mentioned before, several studies identified lower VoTTs. For example Ramjerdi et al. (2010) identified the range of acceptable VoTT based on Norwegian data to be 10.37 - 19.67 €/hour. De Borger and Fosgerau (2008) found a similar range for Danish data. The high level of the found VoTT in this particular study can potentially be explained by the fact that the SC experiment focused on AO decision making. This may cause people to behave and respond differently than when filling in larger surveys that have multiple subjects such as the research by Kouwenhoven et al. (2014). Another explanation could be one of the general limitations of SC research. People may behave strategically in these experiments as the research method does not represent actual decision-making behaviour. However, as no study similar to this one has been published yet, it is impossible to draw general conclusions on the validity of the found VoTT.

- Model

The usage of a RUM-MNL model comes with several limitations. The general limitations of MNL models include first the inability to accommodate for the panel structure of the obtained data. In the SC experiment, individuals make 7 choices and these choices are correlated. A respondent that is very sensitive for travel time is assumed to make all 7 choices accordingly. This cannot be accounted for by MNL models (Chorus, 2018). Furthermore, the Independence from Irrelevant Alternatives property is key to the MNL model. This assumption states that the choice probability ratio of any two alternatives is unaffected by the presence of a third alternative (Chorus, 2012). However, this assumption could lead to unrealistic substitution patterns (Van Cranenburgh, 2017). The MNL model does not allow for modelling heterogeneity within choice data. These limitations reflect rather unrealistic behavioural assumptions underlying the model (Van Cranenburgh, 2016). The limitations could have been solved partially by using for example ML, NL or LC models.

Secondly, the RUM-MNL model does not allow accounting for the fact that different people may use different decision rules, as it only estimates a model based on the RUM theory. The theorem assumes fully compensatory behaviour, and this implies the absence of any choice set effects. However, in practice, choice set effects do often exist. The evaluation of a certain alternative is dependent on the other alternatives available in the same choice set (Chorus, 2018). The RUM-MNL is in line with the assumptions made for substitutability and is therefore the chosen model. Moreover, the McFadden $\rho^2 = 0.328$ indicates reasonable explanatory power, so the RUM-MNL model is considered sufficient for this purpose.

Finally, the linearity assumption may not hold true for all parameters. For example, it is reasonable to assume that a bonus of €100 is more valuable for a student than for someone with a net annual income of €100,000. More specifically, in the case of AO locations, one may experience more disutility of an extra 10-minute drive when this location is at 40 minutes or at 10 minutes. To explore this, the time parameter was tested for linearity. By adding a new parameter β_{TT2}^2, a new model was estimated. Without considering the changes in the rest of the model, this led to a significant estimation of β_{TT2} = -0.0514 and β_{TT2}^2 = -0.00124. The new parabolic utility function for travel time is plotted in Figure 3.4, as well as the initial linear utility function for travel time. Consequently, it can be concluded there is a chance the travel time parameter is not linear. Nevertheless, for the sake of estimating the VoTT and that of simplicity, it is assumed to be linear.

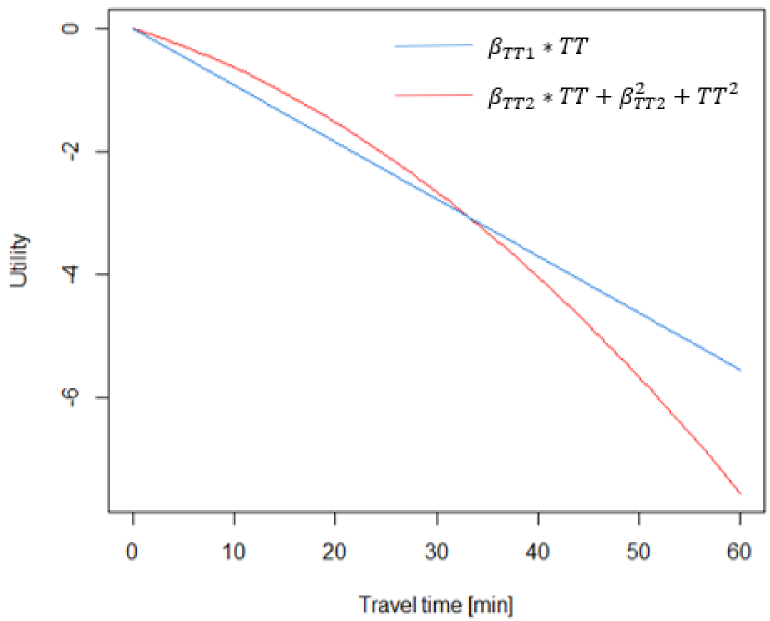


Figure 3.4 Linearity check for time parameter

- General remarks

More generally speaking, the SC experiment has another limitation. It cannot be concluded that respondents did not make any assumptions other than the information given in the choice sets. Inclusion of a list of ‘equal factors’ in the description page of the survey was an attempt to keep the assumptions to a minimum (see Appendix A). Nevertheless, it is possible respondents did still make some assumptions about the different alternatives. For example, they may have associated a hospital at 10 minutes travel time to be their local hospital, while another at 30 minutes travel time may have been associated with the hospital in the next town.

Another limitation of the performed SC experiment is the fact that choice set 5 included an alternative that was dominant. It was not strictly dominant, but 100% of all respondents chose the same alternative. This problem could have easily been avoided if the final survey would have been tested again before distribution.

Finally, the composition of the sample is not representative for the population. This composition is partially caused by the usage of the non-probability convenience sampling method and snowball sampling. The overrepresentation of highly educated, high-income females in the sample may have had its effects on the estimations. A high income may imply indifference for travel costs in this particular range or maybe any range. It is however not possible to assess the severity of the effects of over- or underrepresentation of certain types of respondents in the sample. This makes generalizability of conclusions difficult and risky. The sample could have been more representative for the population if different distribution methods would have been used, such as panels.

3.5 Conclusion

The objective of this chapter was to answer sub-question two: *Which factors influence the decision for women in the Netherlands when choosing a hospital for acute obstetrics care, and to what extent?* Section 2.4 provided a base for the answer. Including the factors as described in the section, as either the factors to be considered equal or as attributes to the alternatives, was done to keep the assumptions made by respondents to a minimum. Furthermore, it allowed for estimation of the parameters that serve as input for the substitutability method in the next chapter.

Despite the limitations as described in Section 3.4.4, the RUM-MNL model has an acceptable level of explanatory power. The significance of all three parameters included in the survey indicate the literature review provided a sound base for the SC experiment. Moreover, it can be concluded travel time plays a major role in the decision of which location to go to for AO care. Women are aware of the fact that being pregnant may imply multiple visits to the hospital. Even if there are no complications related to the pregnancy period or the delivery, the check-ups will happen at the hospital. Also, in case a woman would like to deliver at home according to Dutch traditions, she finds it a lot more comfortable to choose a hospital that is close-by. This can be explained by the fact that, in case of an emergency, this woman may need to be taken to a hospital anyways.

Based on the SC experiment as described in this chapter, the extent to which women find travel costs important is relatively small. In the prior estimation study, the travel cost parameter was not significant on a 99% confidence interval. In the final survey the parameter was found to be significant to a 99% confidence level. However, as the utility effect of the parameter (parameter value multiplied by attribute range) is very small, it can be concluded that for this sample, travel costs are viewed to be relatively unimportant.

It is uncertain if these conclusions hold for women all around the world, or even for women in the Netherlands. This research however provides the best guesses for travel time and travel cost parameters for women in AO decision making, so the following parameters are used as the input parameters for the substitutability calculations:

$$\beta_{traveltime} = -0.0924$$
$$\beta_{travelcost} = -0.0683$$

4 Substitutability

This chapter discusses the substitutability measure and its implications for AO locations in the Netherlands. It first explains the formal model behind the measure, based on the work by Van Wee et al. (2018). Section 4.2 then elaborates on the data collection and preparation phase. Section 4.3 presents the results and aims at giving a visual representation of the insights of substitutability. The subsequent Section 4.4, deals with limitations of the application and results. The last section of this chapter will answer the third sub-question and thereby conclude the chapter on substitutability.

4.1 The formal model

In the conference paper in which Van Wee and Van Cranenburgh (2017) introduce substitutability, they build on accessibility as an assessment method for the quality of land use. Following the definition as used by Geurs and Van Wee (2004, p. 128), accessibility is "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)". Substitutability is very closely related to accessibility and they proposed a definition in the context of travel behaviour. Following the definition of Van Wee, Van Cranenburgh and Maat, substitutability evaluates the quality of the other available options relative to the most preferred option. In their work, Van Wee et al. (2018) compared LogSum accessibility and substitutability. The different formulas that form the mathematical model will be explained using an example of planning a restaurant visit.

The substitutability model is based on the assumption that decision-makers behave rationally and maximize their utility when choosing an alternative. Equation (3) gives the formula for the well-known LogSum measure. V_{jn} equals the observed utility of alternative i from available alternatives J for a certain decision-maker n. C is an unknown constant which indicates that absolute utility cannot be measured. However, in decision-making, the main objective is comparing alternatives and identifying the best alternative in a certain choice set. Absolute values and therefore constant C are irrelevant in this case (Van Wee et al., 2019). LS_n increases when more alternatives are available to the decision-maker. Hence if accessibility is high this means there are attractive alternatives available to the decision-maker. For the example holds, if there are many good restaurants in the vicinity, accessibility is high.

$$LS_n = \ln\left(\sum_J e^{V_{jn}}\right) + C \tag{3}$$

Based on the beforementioned definition of substitutability, equation (4) shows how to calculate substitutability from an ex-ante perspective. Ex-ante implies the researcher assumes a certain probability estimation on the likelihood a decision-maker chooses a certain alternative. Therefore, probability P_i is incorporated in the equation and represents the probability that alternative i is chosen by decision-maker n. $LS_n^{Y=i}$ equals the accessibility (LogSum) without the preferred alternative i. By weighing this with P_i, less preferred alternatives have a smaller impact on the value for substitutability S_n.

$$S_n = \frac{1}{LS_n - \sum_{i=1\ldots J} P_i * LS_n^{Y=i}} \tag{4}$$

To make the substitutability values for different decision-makers comparable to one another, Van Wee et al. (2018) proposed to normalise the value for S_n using equation (5).

$$\hat{S}_n = 1 - \frac{1}{1 + S_n} \tag{5}$$

- **Example: restaurant choice**

For the example it is assumed two decision-makers n and m are analysing which restaurant to go to. Mr n lives in city A and Ms m lives in town B. A visual representation of the restaurants both can choose from and where these are located is given in Figure 4.1. The numbers indicate the travel time to each respective restaurant.

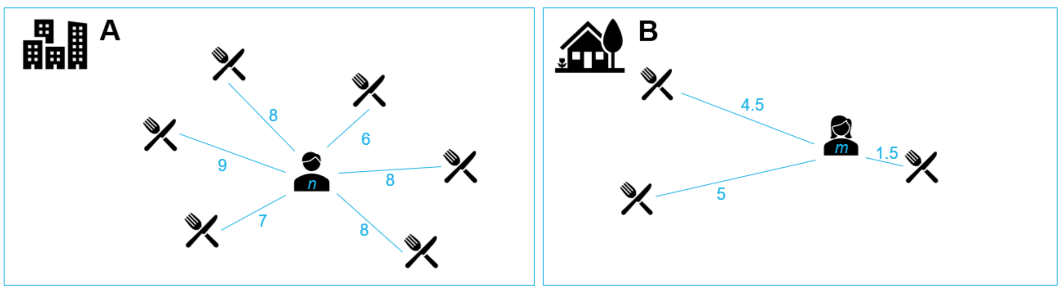


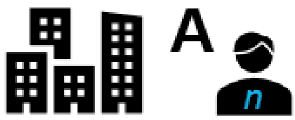
Figure 4.1 Visual representation substitutability example

As can be seen, Mr n has a lot more options available within 10 minutes reach than Ms m. Now to calculate the substitutability values for both, the probabilities P for all alternatives need to be calculated. It is assumed everything but the travel time and travel costs for the alternatives are equal. Then, to calculate P_i, equation (6) is used. This equation is based on the RUM assumption of an MNL model, as explained in Section 3.4.3. The required input for the probability is the utility values of all alternatives available in set J which can be derived using equation (7).

$$P_i = \frac{\exp(V_i)}{\sum_J \exp(V_j)} \tag{6}$$

$$V_i = \beta_{time} * travel\,time_i + \beta_{cost} * travel\,cost_i = \beta_t * TT_i + \beta_c * TC_i \tag{7}$$

For the sake of simplicity, it is assumed β_t and β_c are equal for both n and m. The travel time to each restaurant is given in Figure 4.1. For the travel costs, it is assumed n can walk to every restaurant while m travels by car at a cost of 10 cents per minute. The calculations are given step by step in Figure 4.2.



Restaurant	Travel time (min)	Travel cost (€)
A1	6	0
A2	8	0
A3	8	0
A4	7	0
A5	9	0
A6	8	0

Utilities (assume $\beta_t = -0.2$ and $\beta_c = -0.1$)

$V_{A1} = -0.2 * 6 + \ -0.1 * 0 = -1.2$
$V_{A2} = -1.6$
$V_{A3} = -1.6$
$V_{A4} = -1.4$
$V_{A5} = -1.8$
$V_{A6} = -1.6$

Choice probabilities

$$P_{A1} = \frac{e^{-1.2}}{e^{-1.2} + e^{-1.6} * 3 + e^{-1.4} + e^{-1.8}} = 0.228$$

$P_{A2} = 0.153$
$P_{A3} = 0.153$
$P_{A4} = 0.187$
$P_{A5} = 0.125$
$P_{A6} = 0.153$

LogSums

$LS_n = \ln(e^{-1.2} + e^{-1.6} * 3 + e^{-1.4} + e^{-1.8}) = 0.277$
$LS_n^{Y=A1} = \ln(e^{-1.6} * 3 + e^{-1.4} + e^{-1.8}) = 0.017$
$LS_n^{Y=A2} = 0.111$
$LS_n^{Y=A3} = 0.111$
$LS_n^{Y=A4} = 0.070$
$LS_n^{Y=A5} = 0.143$
$LS_n^{Y=A6} = 0.111$

(Normalised) Substitutability

$S_n = 1/\ (0.277 - ((0.277 * 0.017) + \big((0.153 * 0.111) * 3\big) + (0.187 * 0.070) + (0.125 * 0.143)))$
$S_n = \ 5.235$

$$\hat{S}_n = 1 - \frac{1}{1 + 5.235} = 0.84$$

Restaurant	Travel time (min)	Travel cost (€)
B1	1.5	0.15
B2	5	0.5
B3	4.5	0.45

$V_{B1} = -0.2 * 1.5 + \ -0.1 * 0.15 = \ -0.315$
$V_{B2} = -1.05$
$V_{B3} = -0.945$

$P_{B1} = 0.497$
$P_{B2} = 0.238$
$P_{B3} = 0.264$

$LS_m = 0.384$
$LS_m^{Y=B1} = -0.303$
$LS_m^{Y=B2} = 0.112$
$LS_m^{Y=B3} = 0.077$

$S_m = 2.050$
$\hat{S}_m = 0.67$

Figure 4.2 Example substitutability calculations

The example shows that a higher LogSum value or a higher accessibility does not mean the substitutability value is higher. Because m lives very close to a restaurant, her accessibility value is higher than n's. However, if restaurant B1 would go bankrupt and would no longer be available, the other alternatives for m are a lot less attractive. This is represented in the value for the normalised substitutability $\hat{S}_m$, which is lower than $\hat{S}_n$. The example is a simplification of a real-life situation but shows the added value of substitutability as a measure of how attractive a certain location is. It helps to identify the extent to which the other options available to someone can substitute the preferred option. The upcoming sections will focus on the substitutability in the scope of this research. The next section first discusses the data collection and preparation process.

4.2 Data preparation

Before it is possible to calculate the normalised substitutability values, different input values and parameters need to be obtained. In Chapter 3, the process of gathering parameter values β_t and β_c has been discussed. The values as reported in Table 3.5 are used for the substitutability calculations for AO locations in the Netherlands, so $\beta_t = \beta_{TT} = -0.0924$ and $\beta_c = \beta_{TC} = -0.0683$.

Travel costs are generalized per kilometre travelled. Modal choice will not be included in the research project using car as the default option. When traveling to a hospital, the car is the most-used option (Ravelli et al., 2011). Even when the person that needs to go to the hospital does not own a car, they will most of the times be driven by a friend or family member (Jones et al., 2008). The average distance travelled of Dutch cars is 13,000 kilometre per year per car (CBS, 2018e). The differences between fixed costs for different types of cars are disregarded. An average sized, priced and used car then costs about €0.19 per kilometre (ANWB, 2018). In order to calculate travel costs, one needs travel distances. The same goes for travel times and therefore origins and destinations need to be identified. These will be elaborated on further.

The Google Distance Matrix is used to retrieve travel times and travel distances. An API key is set up and R was used to program and save the travel times and distances for the origin-destination matrix. The package in R that is used to retrieve travel times and distances from the Google Distance Matrix API is called 'gmapsdistance' by Azuero Melo, Rodriguez and Zarruk (2018). Version 3.4 of the package is used. It requires at least an API key, an origin and a destination. The package furthermore allows the user to for example specify the travel mode, the type of traffic model (pessimistic, optimistic or best guess), the departure/arrival time and departure/arrival date. There are several format of origin and destination input this package accepts. It can handle longitude - latitude combinations or specific addresses (Azuero Melo et al., 2018). For the origins or departure locations in this research, a detailed description is given in Section 4.2.1. The destinations will be discussed in Section 4.2.2, and Section 4.2.3 will describe a few of the data preparation steps taken.

4.2.1 Origins

For the substitutability calculations, the origins are represented by houses in the Netherlands, as people mostly travel to hospitals from their homes. Especially when focusing on AO specifically, most women are at home when in need of AO care. The Netherlands works with a zip code system of the following format: 1234XX. For accessibility calculations, RIVM uses four-digit zip codes (Geodan, 2018). The starting point for calculations will include all habited four-digit zip codes in the Netherlands where the number of residents per zip code as reported by CBS (2018a) are used. For example, the so-called 'postbus' numbers are filtered out as these are solely used for corporate mailboxes. Furthermore, there are a few locations, such as the Maasvlakte in the harbour of Rotterdam, that do not have any official residents. These will therefore be removed as well.

As stated, several forms of input are accepted for the origins in the R package. There are three methods that could be used to specify the location of a zip code, which are all three elaborated on before deciding on which to use.

1. ZipCode.

The input for an origin would look as follows: "1011 Amsterdam The Netherlands". This method is fairly easy to use as this information is readily available.

2. Geocode

Geocoding means converting addresses into long-lat combinations. Kahle, Wickham and Jackson (2019) created an R package called 'ggmap' which includes the function 'geocode' that allows a programmer to convert a list of addresses. It requires a location in any type accepted by Google Maps and a Google API key. This method requires one extra step in preparing the input data for the 'gmapsdistance' package.

3. Average

The Dutch governmental institution Cadastre, Land Registry and Mapping Agency (Kadaster) collects and registers data on property (Kadaster, n.d.). They also keep track of the zip codes and addresses in the basic registration of addresses and buildings or Basisregistratie Adressen en Gebouwen (BAG). This database however is only available at a high cost and therefore it was decided to use the latest freely available update, dating from 2010. These data are assumed to be suitable on an aggregated zip code level. The publicly available table with full zip codes, geolocations, street names and municipalities can be downloaded in several formats like excel and SQL (Kraijesteijn, 2016). The average method will calculate the average long-lat combination for all four-digit zip codes on the geolocations of the six-digit zip codes as reported in the table. It will put extra emphasis on areas in a four-digit zip code area that have more registered addresses. This method requires a few extra steps before the locations can be used as input for the 'gmapsdistance' package.

Beforehand, it is uncertain which method would give the most accurate output. Therefore, all three methods are tested on six origins in Amsterdam and three randomly chosen destinations. The results produced using R are presented in Table 4.1 and Table 4.2.

Table 4.1 Test of methods - distance matrix for six origins and three destinations

Distance (km)	**E du Perronlaan 420, 2624NC, Delft**			**Oude Stadsgracht 32, 5611DG, Eindhoven**			**Laan van Tolkien 181, 5661AB, Geldrop**		
Origin/ Method	1	2	3	1	2	3	1	2	3
1011	71.5	71.5	71.1	124.3	124.3	123.9	136.1	136.1	135.7
1012	70.0	70.0	71.1	126.6	126.6	126.7	138.4	138.4	138.5
1013	70.6	70.6	68.1	123.4	123.4	132.9	135.2	135.2	144.7
1014	70.6	70.6	64.4	123.4	123.4	130.3	135.2	135.2	142.1
1015	70.6	70.6	65.7	123.4	123.4	130.6	135.2	135.2	142.4
1016	70.6	70.6	66.1	123.4	123.4	125.5	135.2	135.2	137.2

Table 4.2 Test of methods - time matrix for six origins and three destinations

Time (min)	**E du Perronlaan 420, 2624NC, Delft**			**Oude Stadsgracht 32, 5611DG, Eindhoven**			**Laan van Tolkien 181, 5661AB, Geldrop**		
Origin/ Method	1	2	3	1	2	3	1	2	3
1011	58	58	54	92	92	90	93	93	91
1012	62	62	59	97	97	96	96	96	97
1013	54	54	50	88	88	93	89	89	94
1014	54	54	45	88	88	88	89	89	90
1015	54	54	51	88	88	94	89	89	95
1016	54	54	54	88	88	97	89	89	99

As can be seen, all outcomes for method 1 and 2 or the ZipCode and Geocode method are the same. After thoroughly researching the information attached to the 'gmapsdistance' package, it became clear this package uses the same geocode script to convert a zip code into a geolocation (Azuero Melo et al., 2018). Therefore, the results produced by these two methods are exactly the same. However, even more notable is the fact that the results for method 1 and 2 for the latter four origins are the same. To check what has caused this problem, the locations provided by 'geocode' and the Average method are displayed on a map. This map, created using Google Maps as a background, can be viewed in Figure 4.3. The map shows were it wrong with the travel distance and travel time calculations by Google API. The red pin located in the middle of the '1011' area represents the geocode output for 1011. The red pin with a four next to it, in the bottom right of the same area, indicate the geocodes for 1012 to 1016. Consequently, all calculations from these four zip code areas resulted in the same travel times and distances. Clearly, the blue pins show a better representation of the zip code areas.

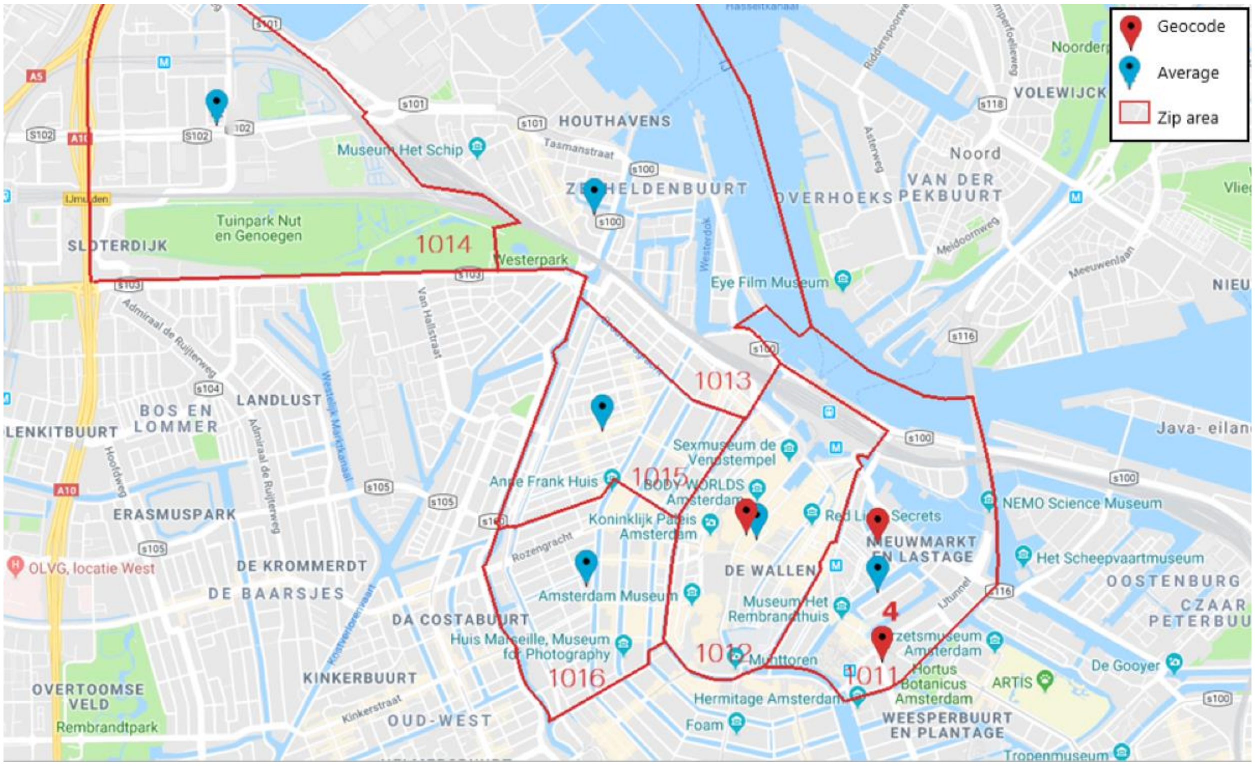


Figure 4.3 Test of methods - Location specifications for two methods

Concludingly, method 3 or the average method is used. Despite the fact that the retrieved database is almost 10 years old, this seems the best option based on the test illustrated above. To achieve and simplify the use of this method, the zip code table as retrieved from SQLblog is prepared using R. The outcome is a table that contains the four-digit zip codes and the averages of longitude latitude combinations.

4.2.2 Destinations

The travel times ware calculated from these four-digit zip codes to the AO locations in the Netherlands. The available destinations are the 78 AO locations that were open in December 2018, as presented in Figure 4.4. The full list of hospitals can be found in Appendix F. The acquisition of the travel times and distances is done using the data available in Google Maps. This way, the travel times by car and distances between locations come as close to the reality as possible. The script that is used to attain these values using R is given in Appendix G, just as the other scripts used for data preparation. The most important steps taken will be described in the upcoming sections.

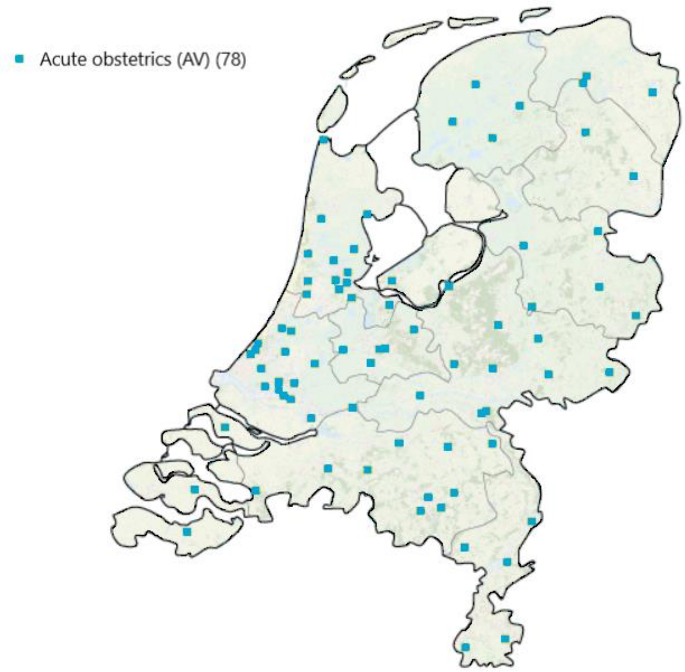


Figure 4.4 The 78 AO locations, updated December 2018 (adapted from RIVM)

4.2.3 Data checks and preparation

The most important steps taken in data preparation have to do with the required format of the input of the Google Distance API. The origins are converted into a vector of ‘long+lat” combinations, given in degrees. The destinations are converted into a vector based on full addresses, also separated by a ‘+’ sign. As running the script can take approximately 48 hours for 20 destinations, this would cause variation in traffic situation for instance during rush hours. The departure time is therefore set to 11:00 am on June 16, 2020, to make sure the travel times do not differ due to congestion.

The ‘gmapsdistance’ package did not work properly for some of the zip codes on the islands located in the north of the Netherlands. The Google Distance Matrix API was not able to find a route between zips ‘8899’ on Vlieland and ‘9166’ on Schiermonnikoog. The boat routes between these islands and the mainland are not officially registered in Google Maps. These have been adapted manually, using the travel time to the closest port. The boat time was then added to this and finally the travel times and distances were copied from the arrival ports. This is also explained in the scripts individually. The next section discusses the results of the substitutability model.

4.3 Results

Using R, the values for minimum travel time, LogSum accessibility and (normalised) substitutability have been calculated. The script used is Script 11, found in Appendix H. Gephi, an open-source and free network visualization program is used to visualise the results (Bastian, Heymann, & Jacomy, 2009). It allows users to colour code figures based on a certain value. By means of the GeoLayout package, the geolocations have been plotted (Jacomy, 2019). The upcoming sections will briefly discuss the results for the different measures.

4.3.1 Minimum travel time

The first measure that is discussed is the minimum travel time or the travel time to the AO location that is closest to the given zip code, calculated by car. The minimum value is 0.93 minutes, found for four-digit zip code 3015 in Rotterdam, in which the ErasmusMC is located. The highest or maximum value is 178.73 minutes, for four-digit zip code 8897 on Terschelling. Due to the long boat travel time from Terschelling, the twelve highest values are found on this island.

Figure 4.5 gives a visual representation of the found values. However, this figure does not provide much information as most zip codes are coloured green in the map. This is caused by the fact that Gephi automatically uses the equal interval classification method when grouping values into classes. This method is based on the $\frac{(maximum - minimum)}{number\ of\ categories}$ formula. The formula results in equally sized groups in terms of range, but certainly not in group sizes. This way of dividing values into groups does provide insights in how a certain area scores relative to others, as long as there are no very extreme values and the data is fairly evenly distributed (Congalton, 1991). Gephi does not accommodate for other ways of classifying the data. The data will be explored by temporarily removing the extreme values.

As can be seen in Table 4.3, the share of zip codes in each equally sized box of minimum travel times is extremely uneven. To get a better insight in the distribution of the travel time to the closest AO location, the values over 45 minutes have been removed temporarily. The division of travel times for the remaining 4034 zip codes is presented in Table 4.4 and visually pictured in Figure 4.6.

Table 4.3 Split in minimum travel times

Cat	Range	Share	Share (%)
1	< 26.3	3785	93.25%
2	26. 3 - 51.7	251	6.18%
3	51.7 - 77.1	5	0.12%
4	77.1 - 102.5	4	0.10%
5	102.5 - 127.9	2	0.05%
6	127.9 - 153.3	0	0.00%
7	> 153.3	12	0.30%

Table 4.4 Split in minimum travel times (after removal of highest 25)

Cat	Range	Share	Share (%)
1	< 6.45	289	7.16%
2	6.45 - 12.0	1066	26.43%
3	12.0 - 17.5	1274	31.58%
4	17.5 - 23.0	882	21.86%
5	23.0 - 28.5	369	9.15%
6	28.5 - 34.0	130	3.22%
7	> 34.0	24	0.59%

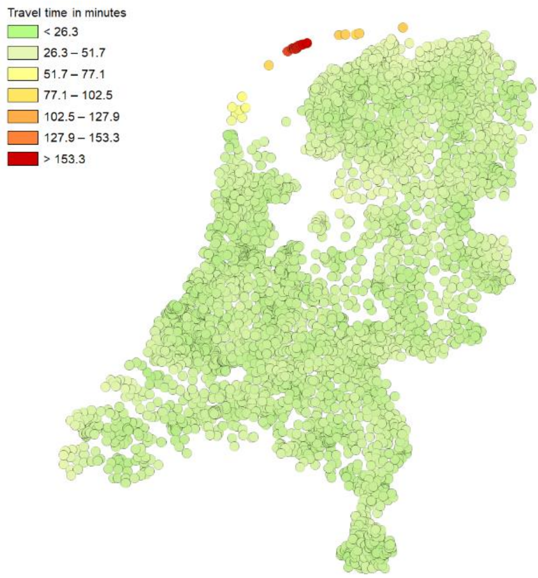


Figure 4.5 Minimum travel time

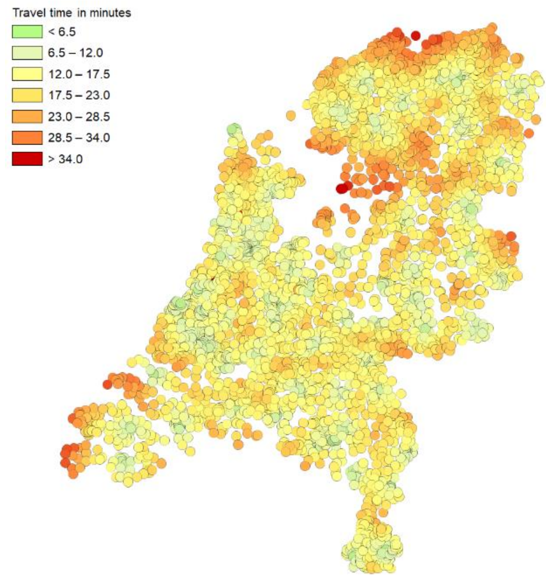


Figure 4.6 Minimum travel time (after removal of highest 25 values)

As expected, some regions in Zeeland, Flevoland and Friesland show critical travel times. Furthermore, a few spots in the border areas report longer travel times to the closest AO location in the Netherlands. As elaborated on before, only locations in the Netherlands have been taken into account, even if a hospital in Belgium or Germany would be closer. This phenomenon occurs in many studies and is often referred to as the boundary problem or boundary effect. This effect will be discussed in the Section 4.4.

To make the results, found by means of the Google Distance Matrix API and the 'gmapsdistance' package in R, comparable to the results published by RIVM, another split in travel times was required. As Gephi automatically divides the colour groups into equally sized ranges, this had to be done manually. This resulted in Figure 4.7. As shown, this map is very similar to Figure 4.8, as published by RIVM in their accessibility analysis (RIVM, 2018a). The biggest difference between the two maps is seen on the island, in particular on Texel, the leftmost island on the map. In this research, the travel time by fast boat and the travel time to the departure port have been summed with the travel times from the arrival port to the AO locations. As the most efficient travel times (assuming no waiting time at the departure port and arrival port) have been used, it is unclear where the difference between both maps comes from. RIVM has not reported on the way the minimum travel times from the islands are calculated. Furthermore, there is no insight in how the data found by RIVM have been aggregated to a full map.

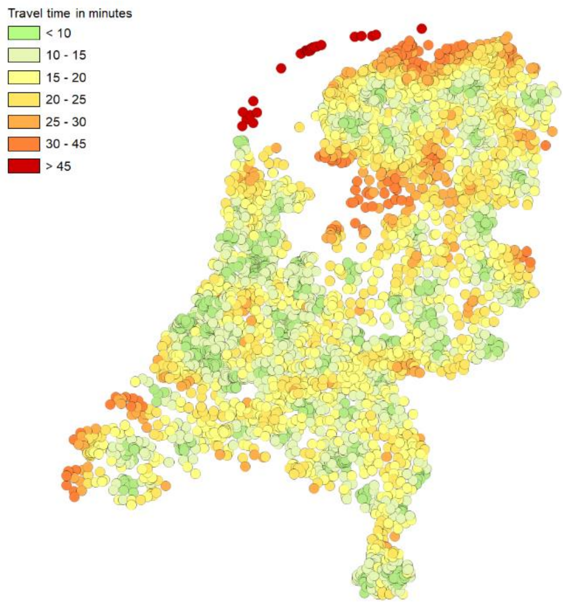


Figure 4.7 Minimum travel times using RIVM ranges

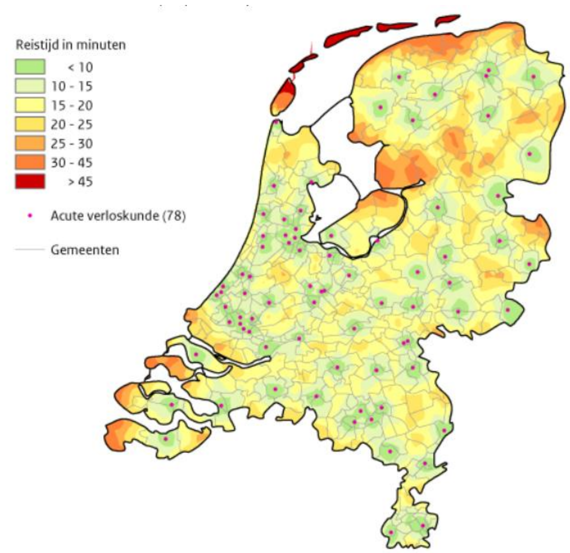


Figure 4.8 Travel time to closes AO 2018. Reprinted from Acute zorg: Regionaal & Internationaal: SEH, by RIVM, November 14 2018, retrieved from https://www.volksgezondheidenzorg.info/

4.3.2 LogSum

Just as the minimum distance values, the LogSum outcomes show almost every region in the Netherlands is fairly well-covered, when compared between all 4059 values. The minimum value is -16.73, found for four-digit zip code 8897 on Terschelling. The maximum value is 1.06, in the north of Rotterdam at zip code 3039.

As can be seen in Table 4.5, the share of zip codes in each equally sized box of LogSum values is very uneven. To get a better insight in the distribution of LogSum values, the values under -4.03 have been removed temporarily. The division of the remaining 4034 zip codes is presented in Table 4.6. The visual representation on the map is found next to the initial figure, in Figure 4.10.

Table 4.5 Split in LogSum values

Cat	Range	Share	Share (%)
1	> - 1.49	3500	86.23%
2	-1.49 - -4.03	534	13.16%
3	-4.03 - -6.57	7	0.17%
4	-6.57 - -9.11	3	0.07%
5	-9.11 - -11.65	3	0.07%
6	-11.65 - -14.19	0	0.00%
7	< -14.19	12	0.30%

Table 4.6 Split in LogSum values (after removal of lowest 25)

Cat	Range	Share	Share (%)
1	> 0.38	476	11.80%
2	0.38 - -0.29	946	23.45%
3	-0.29 - -0.97	1393	34.53%
4	-0.97 - -1.64	829	20.55%
5	-1.64 - -2.31	302	7.49%
6	-2.31 - -2.97	78	1.93%
7	< -2.97	10	0.25%

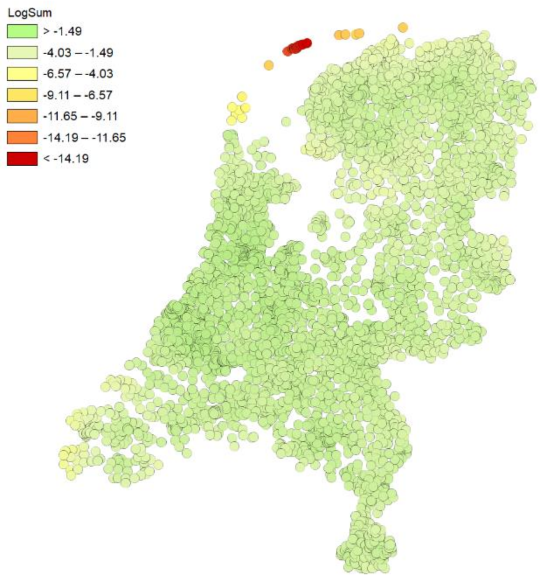


Figure 4.9 LogSum

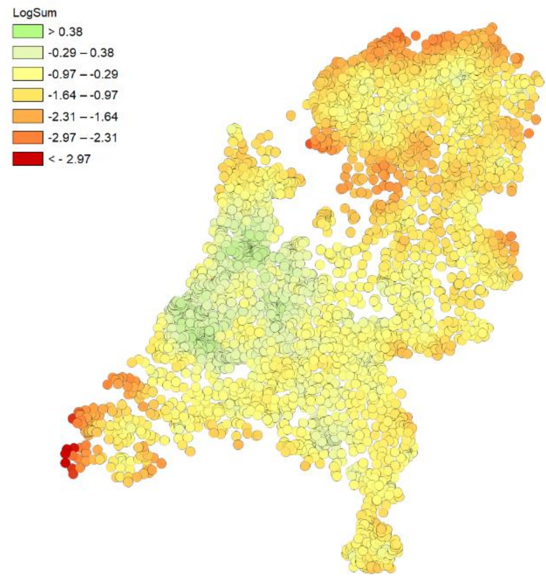


Figure 4.10 LogSum (after removal of lowest 25)

Figure 4.10 provides a bit more information on the division of LogSum values and therefore the accessibility of the AO locations. Critical areas are again located in Zeeland, while the Randstad area scores above average. This has got everything to do with demand and supply. For comparison, the population densities of South Holland and North Holland are 1,311 and 1,062 people/km^2 respectively, while that of Zeeland is only 215 people/km^2 (CBS, 2018d). A higher demand for health care makes it easier to maintain hospitals in certain regions, which leads to better accessibility in this particular area.

4.3.3 Substitutability

Just as the minimum travel time and the LogSum values, the substitutability outcomes show similar results in terms of division based on equally sized ranges, as can be seen in Table 4.7. As elaborated on before, a high value for substitutability means the alternatives available in a certain area are good substitutes for the preferred alternative. The highest value found is 20.6, for zip code 2421 in Nieuwkoop. The lowest value for substitutability is found for zip 1789, located next to Den Helder in North Holland: 0.3. As the map in Figure 4.11 does not provide much information at first sight, it is needed to remove a few values. As the majority of the zip codes fall into the bottom four categories, the values over 11.9 have been removed. In other words, the highest 129 values (3.15% of the total share) have been removed from the overview map and these results are presented in Figure 4.12.

The ‘empty spot’ in the map is located in the Randstad, the area in the Netherlands with the highest levels of population density and many AO locations. The map clearly shows critical areas that have only one AO hospital in its vicinity. It also indicates that in several areas (south in Limburg, most of Zeeland and many areas in the north of the country) the next option is usually not a suitable substitute. The next section elaborates on the normalised substitutability values, which are easier to compare to one another.

Table 4.7 Split in substitutability values

Cat	Range	Share	Share (%)
1	> 17.7	14	0.34%
2	17.7 - 14.8	39	0.96%
3	14.8 - 11.9	76	1.87%
4	11.9 - 9.00	399	9.83%
5	9.00 - 6.10	682	16.80%
6	6.10 - 3.20	1030	25.38%
7	< 3.20	1819	44.81%

Table 4.8 Split in Substitutability values (after removal of highest 129)

Cat	Range	Share	Share (%)
1	> 10.2	1723	4.40%
2	10.2 - 8.56	323	8.22%
3	8.56 - 6.92	384	9.77%
4	6.92 - 5.26	409	10.41%
5	5.26 - 3.61	617	15.70%
6	3.61 - 1.95	1128	28.70%
7	< 1.95	896	22.80%

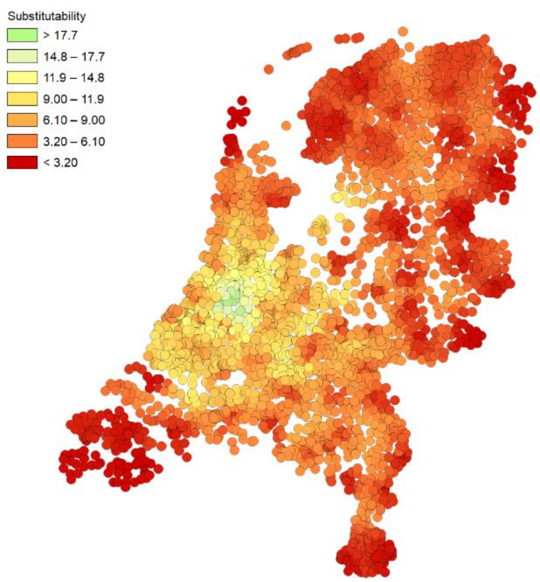


Figure 4.11 Substitutability

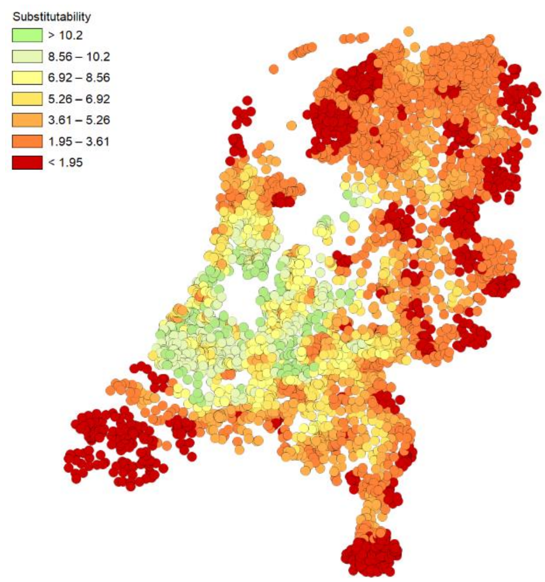


Figure 4.12 Substitutability (after removal of highest 129)

4.3.4 Normalised substitutability

Finally, Figure 4.13 presents the map with normalised substitutability values. The minimum value is 0.230, found for four-digit zip code 1789 which is located in Den Helder, in the far north of the province of North Holland. This makes sense as the only hospital in this area is located here while the next AO location is in Alkmaar, which is 40 minutes or 44 kilometres away. The highest or maximum value is 0.954 for four-digit zip code 2421 in Noordwijk. This is mainly due to the fact that there are about 7 hospitals within 20 minutes from Noordwijk. All of these alternatives are easily substituted by another AO location.

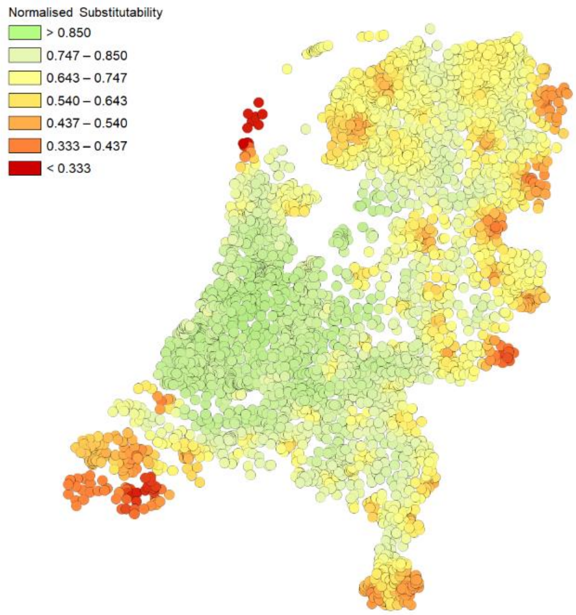


Figure 4.13 Normalised Substitutability

Maybe the most striking thing to the normalised substitutability map is found in the province of Flevoland. A lot of media reported on the problems in this area due to the long travel times to hospitals and the unavailability of beds and personnel. However, the fact that these areas score relatively high in normalised substitutability is in the nature of this measure: it compares the available options instead of rating them. It does not capture the long travel time to the 4 hospitals within an hour of Urk, it just states that whenever someone in this area needs AO care, there are 4 options that could easily be substituted by one another.

Other critical areas are, as expected, found on Texel, in Zeeland and in border areas. Traveling by boat and car and then having just one AO location relatively close by, brings the scores for Texel to a minimum. The people in Zeeland are very dependent on the very few hospitals in this area. If the closest hospital does not have bed or personnel available, a woman in labour will have to travel lengths to the next location. The border areas are difficult to evaluate in a sense that, theoretically speaking, a woman in an emergency situation could go to a cross-border AO location. This so-called boundary effect and other issues are discussed in the next section.

4.4 Discussion

The methodology and the results as presented in the previous sections require revision. This section elaborates on some limitations and critical points of both. It starts by discussing the methodology itself. The chosen application of the substitutability model is based on a linear-additive RUM-MNL model. Consequently, the limitations as discussed in Section 3.4.4, also hold true for this chapter.

The substitutability calculations are based on several other input parameters. On the one hand, the travel times and travel distances are fairly straightforward and not subject to change on the short term. It is expected that the unavailability of up to date data on zip codes may have caused some minor discrepancies in the obtained times and distances. This could have been solved by the purchase of up to date data, but it is considered to have only a neglectable effect on the end results. On the other hand, the cost and time parameters are based on a SC experiment. The substitutability values hold true for the sample, but it is questionable whether the results would be the same for the entire female population. In other words, the substitutability outcomes are very dependent on the validity of the cost and travel time parameters. This makes the results subject to reliability and validity issues.

Furthermore, the unexpected importance of the recommendation parameter in the SC experiment makes it questionable whether the usage of only cost and time parameters provide a sound base for substitutability. It is uncertain whether the factors that have been neglected in the utility and therefore probability estimations of the substitutability calculations would have resulted in completely different outcomes. The high utility effect of β_r does put pressure on the validity of the substitutability results.

Another critical point is the strong influence the beta and cost parameters have on the results. This can be shown using a sensitivity analysis. Multiplication of the value for β_{TT} by two to $\beta_{TT} = -0.1848$ and keeping $\beta_{TC} = -0.0683$ means $VoT_{extreme1}$ is 162.34 €/hour. The corresponding substitutability values are shown in Figure 4.14. Keeping the $\beta_{TT} = -0.0924$ and multiplying β_{TC} by two to $\beta_{TC} = 0.1366$ so $VoT_{extreme2}$ is 40.59 €/hour, leads to the outcomes as shown in Figure 4.15. As can be seen, the results look very different, despite the small change in parameter values. Hence, the results as discussed in the previous section are vulnerable.

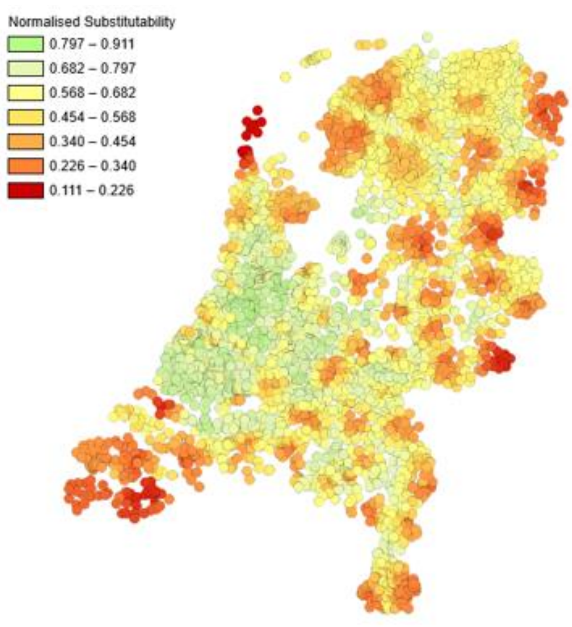


Figure 4.14 Normalised Substitutability Extreme VOT 1

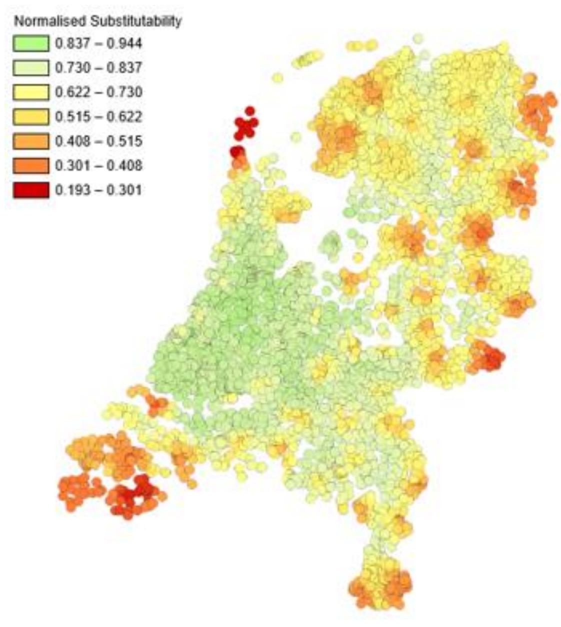


Figure 4.15 Normalised Substitutability Extreme VOT 2

Another limitation of the research and maybe the substitutability model in itself is that it only accounts for the unavailability of the most-preferred option. But, as has been reported by multiple media sources, midwives sometimes have to call multiple (up to 7) hospitals before finding an available bed for their pregnant client. The inclusion of multiple unavailability would probably have led to different results.

Finally, the analysis is based on the geographical boundaries of the Netherlands. This leads to the same results as when the Netherlands would have been an island: the hospitals just across the border are not considered. For many other applications, one should handle the boundary effect very carefully. An example can be found for a supermarket visit, as someone living close to the country border is not restricted by this border. The chosen boundaries are however neglected in this study, as it is assumed that for obstetrics care decision making, very few people will visit a hospital in Belgium or Germany. This is assumed because the language barrier and insurance regulations are expected to play a role. Furthermore, the Dutch government should aim to create an accessible health care system within their own boundaries. Nevertheless, in for example emergency situations, a woman in need could still decide to visit an AO location on the other side of the country border.

4.5 Conclusion

The purpose of this chapter was to answer sub-question three: *What are the differences between the values for accessibility and substitutability in the spatial distribution of the acute obstetrics locations in the Netherlands?* The commonly used LogSum method has been used to assess accessibility. Furthermore, the minimum travel times have been identified as these are used for the identification of sensitive AO locations by RIVM (Kommer et al., 2017). The minimum travel times have ground in the minimum distance method as presented in the literature study in Section 2.2. The normalised substitutability outcomes have been compared to these two measures. The first part of this section elaborates on the general differences, while Section 4.5.2 discusses the differences from an aggregated perspective.

4.5.1 Major differences in measure values

It was expected that the differences between minimum travel times and substitutability values would be large. A short travel time may lead to a low substitutability value, in case an AO location very close-by may have relatively unattractive substitutes. It does however not necessarily have to, as a certain zip code may be surrounded by a few AO locations at a 10 minute drive. The highest minimum travel times are found on the islands, caused by the long travel time by boat. The lowest normalised substitutability values are however not found on the islands.

To see whether or not there exists a relationship between the minimum travel time and normalised substitutability value, the scatterplot as shown in Figure 4.16 has been created. The Pearson correlation is 0.074, so only 0.074^2 or 0.5476% of the variance of the normalised substitutability can be explained by the minimum travel time. Consequently, there is no reason to assume a strong linear relationship. When looking at the scatterplot, it can be concluded there is no clear relationship between the two variables.

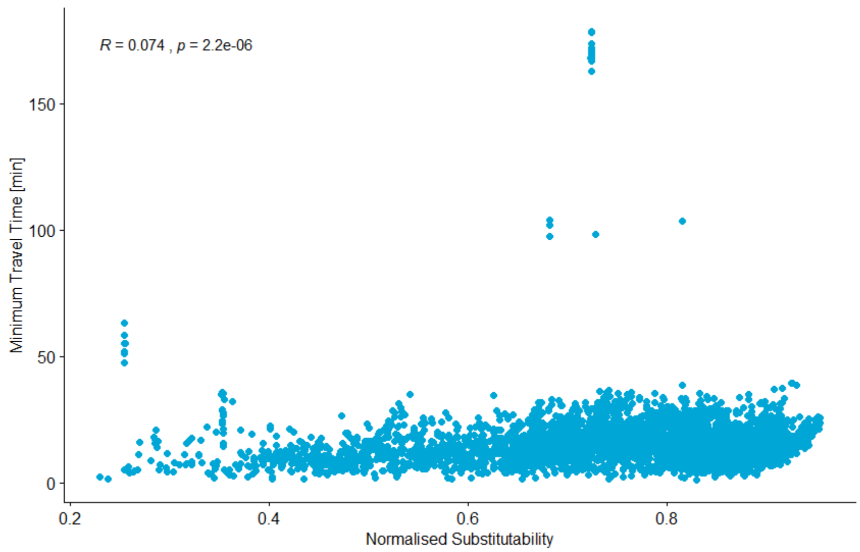


Figure 4.16 Scatter plot with minimum travel time and normalised substitutability

As stated, the minimum travel time and normalised substitutability values show different patterns. A high or low minimum travel time does not directly mean a high or low substitutability value. A very low minimum travel time might even lead to a very low substitutability value. Having one AO location close-by is attractive only when this particular AO location has a bed and personnel available. This grabs the exact thing substitutability helps to identify: the (un)availability of substitutes.

Secondly, the LogSum values. When looking at the mathematical model of substitutability, one might expect the critical areas for substitutability values to be the same as for the LogSum model. The formulation of substitutability is closely related to LogSum and based on the same assumptions. Again, a scatterplot is used to determine the existence of a relationship between the two variables. This scatterplot is shown in Figure 4.17. The p-value indicates the significance of the relationship, and the Pearson correlation coefficient is equal to 0.29. As expected, there is a relationship between the LogSum value and the normalised substitutability values.

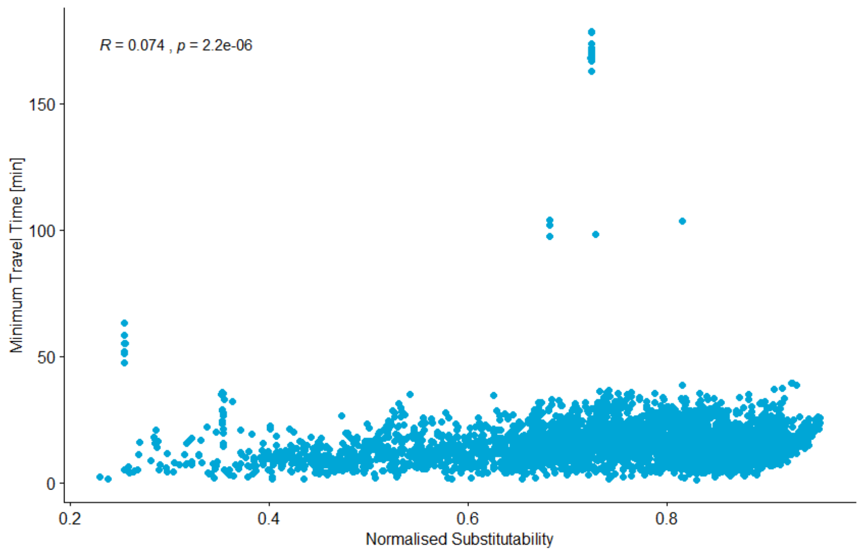


Figure 4.17 Scatter plot with LogSum and normalised substitutability

However, the normalised substitutability values show different critical areas when plotted on a map. Where the LogSum method marks all islands as critical, normalised substitutability marks only Texel as critical. The province of Zeeland is worse off when looking at normalised substitutability, rather than the LogSum values. The border area of the province and the areas next to it score very low for normalised substitutability. Furthermore, the southern part of Limburg, the area of Winterswijk (next to the German border) and the Emmen and Winschoten areas further north have critically low substitutability scores. The lowest value for normalised substitutability is found for zip '1789' in an area next to Den Helder in the far north of North Holland, while the highest value is found for zip '2421' in Nieuwkoop in South Holland. The next section discusses aggregated values, namely for municipalities and provinces.

4.5.2 Differences on an aggregated level

To get a little more insight in the differences between the accessibility and normalised substitutability values, a comparison between the values on a municipality level is made. The values for all zip codes have been aggregated and averaged to their respective municipality. Next, the municipalities have been ranked from 1 to 355 on all three measures, 1 representing the best score and 355 representing the worst score. The five top and bottom rankings are presented in Table 4.9. The ranking in the last column of Table 4.9 is based on a combined score. The rankings have been summed and the 'overall' rank is built on this summed score. The scores are not weighted but solely based on the three ranks.

Table 4.9 Rankings for aggregated measures on a municipality level

Rank	MinTime	LogSum	NormSubst	Overall
1	Beverwijk	Diemen	Nieuwkoop	Oostzaan
2	Geldrop-Mierlo	Oostzaan	Woerden	Amsterdam
3	Leiderdorp	Amsterdam	Uithoorn	Delft
4	Weert	Schiedam	Alphen aan den Rijn	Diemen
5	Oegstgeest	Ouder-Amstel	De Ronde Venen	Schiedam
|				
351	Texel	Texel	Hulst	Delfzijl
352	Vlieland	Schiermonnikoog	Winterswijk	Ameland
353	Ameland	Vlieland	Terneuzen	Veere
354	Schiermonnikoog	Ameland	Den Helder	Sluis
355	Terschelling	Terschelling	Texel	Texel

The bottom rankings for both minimum travel time as well as the average LogSum values are represented by the five islands. Only Texel also appears on the bottom rankings for normalised substitutability, the others do not. This difference can be explained by the fact that the available options for Vlieland, Ameland, Schiermonnikoog and Terschelling are all equally far away. So even though the possibilities are further away (the high minimum travel time and the low LogSum value) the possibilities are good substitutes for one another.

The worst scores for substitutability on a municipality level are found in the border areas with Germany or Belgium, as well as in Den Helder and Texel. Apparently, Den Helder is very dependent on the availability of the Gemini location of the Noordwest Ziekenhuisgroep in Den Helder. The highest scores for substitutability are on the other hand all located in or next to 'het Groene Hart', a thinly populated area located in the middle of the Randstad. When looking at the overall rankings, all municipalities in the top five are also located in the Randstad area. The bottom values are all located in the north of the country, either on the islands or in the province of Groningen or Friesland. These results are in line with the expectations, as one would expect the densely populated areas in de Randstad (provinces of South Holland, North Holland and Utrecht) to get good scores on all three measures.

Next, Table 4.10 presents the average minimum travel times, LogSum and normalised substitutability values, aggregated to a provincial level. The average of the province is based on the average of all municipalities in this particular province. The averaged values and the respective ranks are both displayed. As can be seen, Zeeland is on the bottom of the overall rank, while Zuid-Holland scores best.

Table 4.10 Ranking average minimum travel time, LogSum and normalised substitutability values on a provincial level

Province	Average MinTime	Average LogSum	Average Norm. Subst.	Rank MinTime	Rank LogSum	Rank Norm. Subst.
Drenthe	18.521	-1.1791	0.6961	8	9	7
Flevoland	19.977	-0.8144	0.8613	11	6	3
Friesland	22.756	-1.6608	0.6708	12	11	9
Gelderland	15.022	-0.5522	0.7703	6	5	6
Groningen	18.899	-1.2134	0.6797	9	10	8
Limburg	14.479	-0.8608	0.6366	5	7	11
Noord-Brabant	14.375	-0.4762	0.7917	4	4	5
Noord-Holland	13.259	-0.0845	0.8313	2	3	4
Overijssel	16.781	-1.1177	0.6411	7	8	10
Utrecht	13.380	0.1225	0.8871	3	2	1
Zeeland	18.998	-1.6705	0.4878	10	12	12
Zuid-Holland	12.279	0.2328	0.8807	1	1	2

The biggest difference is seen for the province of Limburg in the south of the country, which scores a lot lower in normalised substitutability than in LogSum and minimum travel times. This can be explained by the fact that the AO locations in Limburg are of vital importance to the people living in the southernmost regions. Another large difference is seen for Friesland, which scores better in normalised substitutability. This can be explained by the fact that the very few options available are far away (the low LogSum and high minimum travel times) are acceptable substitutes for one another (hence the relatively high normalised substitutability score).

The different patterns for all three measures as elaborated on in this section, serve as a guide towards answering the main research question. The next chapter concludes the study by presenting conclusions, future research recommendations and a reflection.

5 Conclusion, recommendations and reflection

The main objective of this study was to explore the substitutability concept and to identify the consequences of including it in the evaluation of the spatial distribution of AO locations in the Netherlands. The research was structured along four sub-questions and a main research question. The remaining sub-question is answered in this chapter. Furthermore, an answer to the main research question is formulated. A suggestion for the spatial distribution of AO locations is done, despite it not being an objective of this research. The second section provides some ideas and recommendations for future research subjects. Finally, Section 5.3 presents a reflection on the quality of the research and a personal reflection on the research and the process.

5.1 Main conclusions

Before being able to answer the main research question, one remaining sub-question needs to be answered. The fourth sub-question was formulated as follows: *What is the added value of including substitutability in a spatial distribution analysis?* Based on the conclusion of Chapter 4, the added value of substitutability can be found in that it offers new insights in the performance of a spatially distributed system. The upcoming section briefly elaborates on the potential of the concept. Section 5.1.2 then concludes the study by answering the main research question.

5.1.1 The potential of substitutability in spatial distribution analysis

This research focused on the current distribution of AO locations in the Netherlands. As it has been shown there are significant differences in the outcomes for the traditional accessibility measures and the substitutability measure, it has the potential to be insightful in other situations as well. In this section, the concept is projected on similar subjects and other subjects. Afterwards, some general conclusions that can be drawn about the substitutability model are discussed.

- Application of substitutability on similar subjects

This study focused on the spatial distribution of AO locations. The substitutability model can also be applied in similar situations, such as the evaluation of spatial distribution of the A&E locations in the Netherlands. When looking at the accessibility of A&E locations by car, the expectation is that the results would be similar to the results found in this study. The results are not directly applicable to the accessibility by ambulance. However, the substitutability model may provide important insights in critical areas for the spatial distribution of ambulance care. The decision on which hospital to go to is made in the ambulance, based on the care the patient is expected to need and on availability of beds and personnel. Substitutability would help assess critical areas in situations where sometimes a bed is unavailable.

Additionally, applying the substitutability model for A&E locations in emergency situations may help release pressure of the A&E system. Imagine the substitutability model has been applied for different specialisations. In some area, substitutability is high: there are three excellent substitutes for the closest A&E location for basic emergency care. At a certain point in time, the ambulance picks up a patient that has broken a leg. Five minutes later, another ambulance comes to the same area for a patient that may have suffered severe brain damage. The substitutability model has shown that only one of the four hospitals in this area has a specialised neurology department. In this situation, the patient with the broken leg should not be brought to this particular hospital, but to one of the other three substitutes. Even if these are located a little further away: the performance of the A&E system would improve. Naturally, additional research is required before drawing conclusions. Amongst others, ethical issues may rise. However, is recommended to further research this matter. Related to the evaluation of AO and A&E spatial distribution, substitutability may also be of use in non-emergency situations. As stated before, the identification of critical locations in terms of substitutability may help improve the performance of the overall system.

- Application of substitutability on other subjects

The substitutability model can also be applied in other fields than the health care sector. For any subject in which the unavailability of the preferred alternative may play a role, substitutability values could lead to other insights than the traditional accessibility measures. This study took the perspective of residential locations as a starting point. From this point of view, substitutability could be used to assess the attractiveness of a neighbourhood. High substitutability values for public transport alternatives would make a neighbourhood a lot more attractive for someone planning to use public transportation for daily travels. Substitutability offers a possibility to capture the effects of planned maintenance work on the train network, while regular accessibility measures would not be able to evaluate the effects properly.

Moreover, substitutability has the potential to be useful from the perspective of planners in for example relocation decision making. Instead of taking residential locations as a starting point, one could approach substitutability from a demand side perspective. This way, substitutability could assess attractiveness of a certain location based on the substitutes that are available for potential clients, as these substitutes would affect demand.

- General conclusions on the substitutability concept

The ease of application makes for an attractive future research subject. This study focused on the comparison of the minimum distance method and the LogSum method with the substitutability method. However, by means of mapping the results, the substitutability values can also easily be compared to other accessibility measures. Examples include, amongst others, the choice-set method or the Hansen method (see Table 2.2). Furthermore, the substitutability concept is very flexible. This particular research used the LogSum method as a base of the mathematical formulation. However, one could explore the results of other types of models, as will be elaborated on in Section 5.2.

The substitutability measure should mainly be viewed as a complementary measure. In most accessibility or spatial distribution analyses, other factors that are not included in the substitutability model play a role. It is recommended to apply the substitutability model after applying the traditionally used accessibility methods and see if the results provide different insights. Another possibility would be to incorporate constraints in the substitutability model. In this study for example, this would mean including the rule that for every area, at least one AO location should be within 45 minutes reach. This way, both the minimum distance as well as the substitutability model could be applied at once.

Finally, the substitutability method allows for testing shifts in parameter values. One could therefore easily get different results for the effects of a new bus service for young people living in urban areas compared to elderly people living in rural areas. It can be concluded that the substitutability measure as introduced by Van Wee & Van Cranenburgh (2017) has at the very least opened up a new sector of the spatial distribution research field and potentially even more.

5.1.2 Concluding the study

As all sub-questions have been answered, the main research question can now be answered. The main research question was formulated as follows:

> *What are the consequences of including the concept of substitutability in the evaluation of the spatial distribution of acute obstetrics locations in the Netherlands?*

Based on the comparison of the outcomes for the minimum travel time to the closest hospital, the LogSum values and the substitutability values new critical areas have been indicated. RIVM has very recently updated the list of hospitals marked as 'sensitive' for AO care. Due to the closure of the AO in Lelystad, there were some shifts in the list of sensitive hospitals (Kommer et al., 2019). The following areas, besides the sensitive locations as identified by RIVM, should be handled with care when reconsidering the spatial distribution of AO locations: the southern region of Limburg and the Emmen area.

Hence, it is suggested to mark the UMC in Maastricht and the Treant Scheper in Emmen as sensitive as well. These hospitals do not directly affect the number of women that cannot reach an AO location within the maximum ambulance trip time of 45 minutes. However, when considering the additional insights offered by the substitutability values, these hospitals show to be of critical value to the spatial distribution of AO locations. The unavailability of beds in one of these hospitals would have severe consequences for the well-being of pregnant females in these regions. The normalised substitutability values, the sensitive locations and the additional suggestions for sensitive locations are visualised in Figure 5.1. The red areas on the map show areas of which the preferred AO location cannot easily be replaced by another in case of unavailability. It is important to note that for this figure, a different cartography method has been used. For the sake of interpretability, the natural breaks method has been applied to create a map that shows a larger contrast between the different normalised substitutability values (Congalton, 1991). The blue dots represent hospitals that are marked as sensitive according to the latest update published by RIVM (Kommer, Gijsen, & Giesbers, 2019). The purple dots represent the proposed additional sensitive locations, based on the results of the substitutability model.

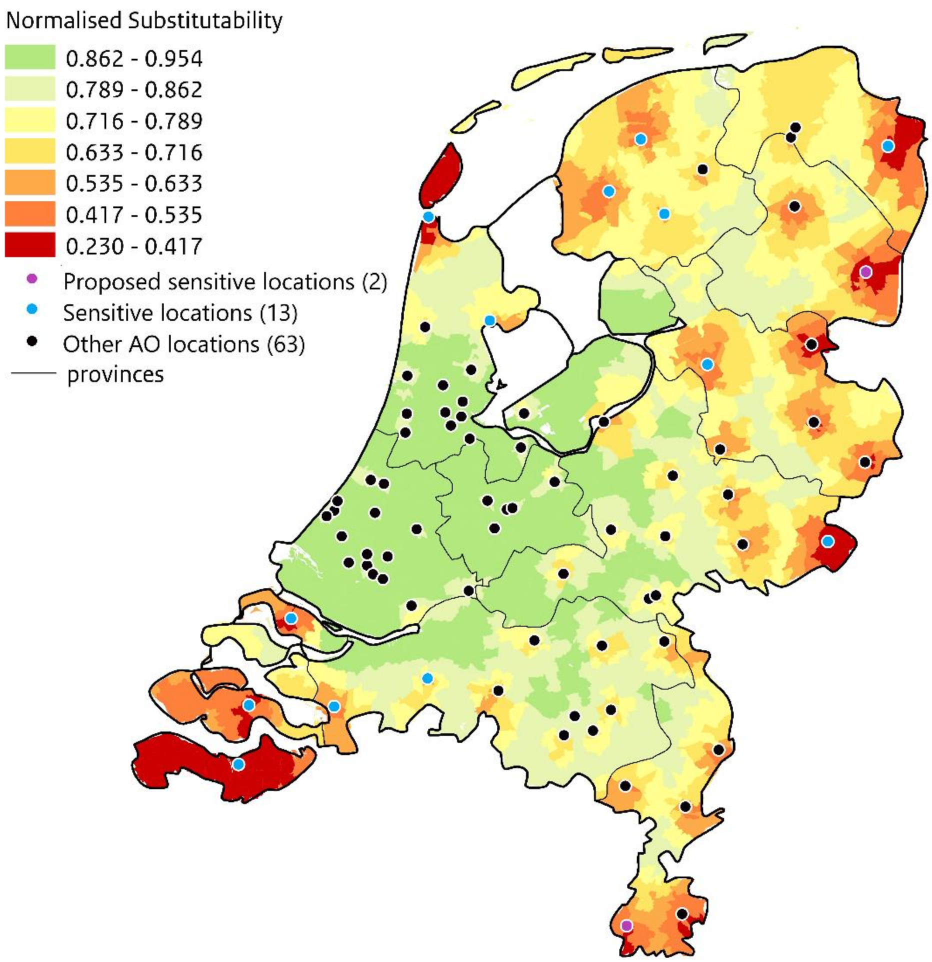


Figure 5.1 Normalised substitutability values and suggestions for sensitive locations

Following the abovementioned considerations, the spatial distribution of the AO locations in the Netherlands is of an acceptable standard. The fact that the Netherlands is very densely populated makes the system manageable. These statements hold true for when any AO location has a bed available for a pregnant woman. However, the sector has been facing two major challenges: the difficulties to find personnel and the increasing concentration on current AO locations caused by the decreasing number of locations. These challenges have led to unavailability of beds for women at the verge of delivery. This unavailability has been captured in this research by means of the substitutability concept.

The substitutability values have been calculated based on an SC experiment among mostly highly educated females in the Netherlands. Based on the comparison of the normalised substitutability values and the accessibility measures in place, it can be concluded the substitutability concept shed a new light on the spatial distribution of AO locations in the Netherlands. A suggestion has been done on the usage of substitutability for the sensitivity analysis. The next section discusses some research recommendations that may help improve the quality of the results obtained by this study.

5.2 Research recommendations

As has been discussed in the previous section, the concept of substitutability has opened up a new path in accessibility as well as spatial distribution research. It has already been mentioned that this study merely serves as a first exploration of substitutability for the spatial distribution of AO locations. This section includes just a few remarkable recommendations related to this research project, as the list of possibilities for future research would otherwise be almost endless. The first four research ideas are related to substitutability, while the latter four have to do with SC experiments.

1. Inclusion of more parameters than just cost and time

The model in this research project focused on the travel cost and travel time parameter. However, for other types of research objectives, it might be relevant to include other parameters. For the case of AO locations in particular, one could for instance consider a quality measure, waiting times, reputation or the chance of bed-unavailability.

2. Usage of a different base model

For this research, the linear-additive RUM-MNL model served as the basis. The usage of another model, based on different parameters, may influence the substitutability values. A comparison between different types of models and the subsequent outcomes for substitutability may offer new insights in the power of substitutability

3. Different model formulations

The LogSum served as a base for this research project. The substitutability values were therefore also related to the LogSum formulation. An interesting future research direction is that of other mathematical formulations. A topic could be the differences between the substitutability outcomes for different types of formulations. Van Wee et al. (2018) already proposed an alternative that compares the utility of the second-best option compared to the first best option. Another formulation could be one that takes the unavailability of more than one preferred alternative into account.

4. Research from the perspective of hospitals

The substitutability calculations in this research were performed from the perspective of the hospital user. The origins in the model were represented by potential obstetrics care seekers. In other words, it took the supply side approach. An interesting direction for future research is that from the demand side perspective. Destinations and origins could be swapped, so for example a commercial party could investigate substitutability values. It is expected substitutability could complement for instance the coverage model when estimating demand after relocation.

5. Extended SC experiment for AO decision making, with a larger and representative sample of the female population of the Netherlands

The SC experiment as conducted for this research was kept fairly simple. As the identification of reliable travel cost and travel time parameters was the major objective of the experiment, this was a sufficient approach. However, as shown by the limited exploratory power of the estimated model, there is room for improvement. Researchers should make sure to test their research on respondents in order to avoid dominance in choice set. Future research for AO decision making among women in the Netherlands should furthermore carefully consider the representativeness of the sample. The inclusion of lower educated women, retired women and women living in rural areas would help improve the validity of the parameters.

6. Assessment of choice set and awareness effects

An important point to take into consideration has already been introduced by Chorus (2018). Is a decision-maker always aware of the available options? How does this effect decision making? For the current research specifically, all AO locations were considered to be alternatives to a decision-maker. However, in practice, someone would not seriously consider a hospital on the other side of the country. The assessment of choice set effects on the one hand and on the other hand awareness effects is therefore an interesting future research direction.

7. Exploration of additional models for AO decision making

Comparable to recommendation 1, the usage of other models next to the used RUM-MNL model such as ML, NL or LC models would help improve the validity of the parameters. Future research could focus on finding the statistically seen best model to explain the behaviour of women in AO decision making

8. Revealed preference experiments

Revealed preference experiments into AO decision making would improve the validity of the estimation parameters. The major disadvantage of revealed preference experiments compared to SP experiments is that they are very time consuming and require many respondents. However, it is a way to assess real-life decision making and could potentially be conducted based on data that is already tracked in hospitals at this point.

5.3 Reflection on the quality of the results

Throughout this study, many limitations and discussion points have already been addressed. This section will provide a short review on the quality of the research results that have not been presented yet.

The reflection on the quality of the results is done by reflecting on reproducibility and validity of the results. The literature study that describes empirical background of the distribution of AO locations is difficult to reproduce and may, due to its qualitative character, induce bias on the review. The same goes for the literature study on accessibility measures. These two studies are dependent on the researcher, as the researcher decides which findings are relevant. Therefore, the studies reflect the opinion of the researcher. On the other hand, the literature study for hospital decision making was more structured. The different steps and decisions taken are elaborated on extensively, which makes the literature review reproducible.

The next step in the study consisted of the SC experiment. The results of the SC experiment are dependent on a number of assumptions. The attributes, the attribute levels, the choice set construction, the used priors, the way of distributing and the sample all have an influence on the obtained data. Moreover, the way of handling this data can cause bias on the results. The inclusion or exclusion of dominant alternatives and the choice for a certain model lead to biased outcomes. The process of the SC experiment and the subsequent data preparation phases are conducted in a structured way. Still, the SC experiment is prone to reproducibility issues, as other researchers may have different views on the taken decisions throughout the process.

The final step of the study included the substitutability calculations. Again, the choice for a specific discrete choice model and the found input parameters influence the outcomes. However, the different steps in the application are described and argued for extensively. Another researcher can easily use the provided scripts to retrieve the exact same numerical results. A ready-to-use script for the substitutability model is presented in Appendix H (Script 11).

A validity issue was risen by a few pilot respondents. It was questioned whether people really consider travel costs when deciding in an acute or emergency situation. The answer to this question probably is no. In an emergency situation, especially in the case of obstetrics care, a woman would most probably want to be taken care of as soon as possible. This issue raised questions in terms of validity: why would it be relevant to include a cost parameter in the assessment of the spatial distribution of AO locations? In the description of the final survey, it was attempted to overcome this issue. The respondents were told to assume there was no direct need for AO care, as there were no complications during pregnancy. They were asked to choose a hospital, knowing they would have to visit this hospital multiple times. This assumption made it unnecessary to pick the closest hospital. It was shown this description worked, as there were no non-traders in the data set. No respondent solely picked the alternative with the shortest travel time.

Consequently, one could question the decision as to why only AO locations (so hospitals that meet the AO requirements by RIVM) were considered in the substitutability calculations. This decision was made based on the assumption that there is always a certain chance a pregnant woman has to deliver at a hospital, due to sudden complications in the labour phase. In that case, the only hospitals this woman could choose from would have to be official AO hospitals. Therefore, it was decided to focus on AO locations, as these form the key locations in the spatial distribution of the obstetrics care sector in the Netherlands. One could question the acceptability of using the time and cost parameters retrieved from the SC experiment for the substitutability calculations. Future researchers are very welcome to improve the validity of the parameters in any way they consider appropriate, as this would definitely be of added value from a scientific perspective.

Concludingly, based on the aforementioned considerations, there are several implications that put pressure on the quality of the results of this study. All steps taken in the research contain a certain level of subjectivity and influence from the researcher. Consequently, there is room for improvement on different aspects and additional validation studies are recommended.

List of References

Adamowicz, W., Louviere, J. J., & Swait, J. D. (1998). *Introduction to Attribute-Based Stated Choice Methods*.

Adams, E. K., Houchens, R., Wright, G. E., & Robbins, J. (1991). Predicting Hospital Choice for Rural Medicare Beneficiaries: The Role of Severity of Illness. *Health Services Research*, *26*(5), 583–612.

Addelman, S. (1962). Orthogonal Main-Effect Plans for Asymmetrical Factorial Experiments. *Technometrics*, *4*(1), 21–46.

AIHW. (2017). *Rural & remote health*. Canberra. Retrieved from https://www.aihw.gov.au/reports/rural-health/rural-remote-health/contents/access-to-health-services

Aloef, F. A. (2015). *Bayesian Design of Discrete Choice Experiments for Valuing Health State Utilities*. The University of Sheffield.

ANWB. (2018). Autokosten berekenen: bereken kosten per maand en per kilometer. Retrieved December 12, 2018, from https://www.anwb.nl/auto/autokosten#/autokosten

Australian Bureau of Statistics. (2017). *Health Service Usage and Health Related Actions, Australia, 2017. Australian Bureau of Statistics*.

Azuero Melo, R., Rodriguez, D., & Zarruk, D. (2018). Package “gmapsdistance.” Retrieved from https://cran.r-project.org/web/packages/gmapsdistance/gmapsdistance.pdf

Baray, J., & Cliquet, G. (2013). Optimizing locations through a maximum covering/p-median hierarchical model: Maternity hospitals in France. *Journal of Business Research*, *66*(1), 127–132. https://doi.org/10.1016/J.JBUSRES.2012.09.003

Bastian, M., Heymann, S., & Jacomy, M. (2009). *Gephi: An Open Source Software for Exploring and Manipulating*.

Basu, J., & Cooper, J. (2005). Out-of-Area Travel From Rural and Urban’ Counties: A Study of Ambulatory Care Sensitive Hospitalizations for New York State Residents. *The Journal of Rural Health*, *16*(2), 129–138.

BatchGeo. (2019). Retrieved from https://nl.batchgeo.com/

Batterink, M., Reitsma, J., Bakker, L., Pomp, M., & Plu, R. (2016). *Ziekenhuisfusies en kwaliteit van zorg. Onderzoek naar de effecten van ziekenhuisfusies op de kwaliteit van zorg*. Significant.

BDO. (2018). *Benchmark Ziekenhuizen 2018*.

Ben-Akiva, M., McFadden, D., Train, K., Walker, J., Bhat, C., Bierlaire, M., … Munizaga, M. A. (2002). Hybrid Choice Models: Progress and Challenges. *Marketing Letters*, *13*, 163–175.

Beukers, P. D. C., Kemp, R. G. M., & Varkevisser, M. (2014). Patient hospital choice for hip replacement: empirical evidence from the Netherlands. *The European Journal of Health Economics*, *15*(9), 927–936. https://doi.org/10.1007/s10198-013-0535-7

Bhat, C., Kockelman, K., Qinglin, C., Handy, S., Mahmassani, H., & Weston, L. (2000). *Urban Accessibility Index: Literature Review*. Austin, TX.

Blaxter, L., Hughes, C., & Tight, M. (2010). *How to Research* (3rd ed.). Berkshire, England: Open University Press.

Bliemer, M. C. J., Rose, J. M., & Chorus, C. G. (2017). Detecting dominance in stated choice

data and accounting for dominance-based scale differences in logit models. *Transportation Research Part B: Methodological*, *102*, 83–104. https://doi.org/10.1016/J.TRB.2017.05.005
Bronstein, J. M., & Morrisey, M. A. (1990). *Determinants of Rural Travel Distance for Obstetrics Care*. *Medical care* (Vol. 28). https://doi.org/10.1097/00005650-199009000-00013
Bronstein, J. M., & Morrisey, M. A. (1991). Bypassing Rural Hospitals for Obstetrics Care. *Journal of Health Politics, Policy and Law*, *16*(1), 87–118.
Brown, J. D. (2001). *Using surveys in language programs*. Cambridge: Cambridge University Press.
Brownstone, D., & Small, K. A. (2005). Valuing time and reliability: assessing the evidence from road pricing demonstrations. *Transportation Research Part A*, *39*, 279–293. https://doi.org/10.1016/j.tra.2004.11.001
Bruins, B. (2018, October 25). Faillissement MC Slotervaart en MC IJsselmeerziekenhuizen [Letter of government]. Retrieved from http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2015/02/06/kamerbrief-over-verbeteren-kwaliteit-en-betaalbaarheid-zorg.html
Buczko, W. (1992). What affects rural beneficiaries use of urban and rural hospitals? *Health Care Financing Review*, *14*(2), 107–114.
Burns, L. R., & Wholey, D. R. (1992). The impact of physician characteristics in conditional choice models for hospital care. *Journal of Health Economics*, *11*(1), 43–62. https://doi.org/10.1016/0167-6296(92)90024-U
CBS. (2015a). *Meer dan de helft van de werknemers bij pensionering 65 jaar of ouders*.
CBS. (2015b). StatLine - Personen in bezit van auto of motor; persoonskenmerken, 2010-2015. Retrieved April 16, 2019, from https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81844ned&D1=a&D2=a&D3=0,8-22,26-31&D4=l&VW=T
CBS. (2018a). Nabijheidsstatistiek. Den Haag: Centraal Bureau voor de Statistiek. Retrieved from https://www.cbs.nl/nl-nl/onze-diensten/methoden/onderzoeksomschrijvingen/korte-onderzoeksbeschrijvingen/nabijheidsstatistiek.
CBS. (2018b). StatLine - Bevolking; kerncijfers. Retrieved April 16, 2019, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37296ned/table?ts=1555406073472
CBS. (2018c). StatLine - Labour participation; key figures. Retrieved April 16, 2019, from https://opendata.cbs.nl/statline/#/CBS/en/dataset/82309ENG/table?ts=1555405111052
CBS. (2018d). StatLine - Regionale kerncijfers Nederland. Retrieved December 6, 2018, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70072ned/table?ts=1544099989345
CBS. (2018e). Statline - Verkeersprestaties personenauto's; kilometers, brandstofsoort, grondgebied. Retrieved December 12, 2018, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80428ned/table?ts=1540904148773
CBS. (2019a). Begrippen. Retrieved March 16, 2019, from https://www.cbs.nl/nl-nl/onze-diensten/methoden/begrippen
CBS. (2019b). *Doorsnee inkomen werkenden al 10 jaar vrijwel constant*. *Centraal Bureau voor de Statistiek*.
CBS. (2019c). StatLine - Bevolking; hoogstbehaald onderwijsniveau en onderwijsrichting. Retrieved April 16, 2019, from

https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82816NED/table?ts=1555405678613
CBS. (2019d). StatLine - Nabijheid voorzieningen; afstand locatie, regionale cijfers. Retrieved April 18, 2019, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80305ned/table?ts=1555599552788

ChoiceMetrics. (2018). *Ngene 1.2 User Manual and Reference Guide*. Sydney, Australia: ChoiceMetrics.

Chorus, C. G. (2012). Random Regret Minimization: An Overview of Model Properties and Empirical Evidence. *Transport Reviews*, *32*(1), 75–92. https://doi.org/10.1080/01441647.2011.609947

Chorus, C. G. (2018). Statistical Analysis of Choice Behaviour. Lecture 1: Choice behaviour modeling and the MNL-model [Powerpoint slides]. *Delft University of Technology*.

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, *37*(1), 35–46. https://doi.org/10.1016/0034-4257(91)90048-B

De Borger, B., & Fosgerau, M. (2008). The trade-off between money and travel time: A test of the theory of reference-dependent preferences. *Journal of Urban Economics*, *64*(1), 101–115. https://doi.org/10.1016/J.JUE.2007.09.001

De Jong, G., Tseng, Y., Kouwenhoven, M., Verhoef, E., & Bates, J. (2007). *The Value of Travel Time and Travel Time Reliability*.

De Looff, E. J. (2017). *Value of Travel Time Changes as a Result of Vehicle Automation: a Case-Study in the Netherlands*. Delft University of Technology.

Dekking, F. M., Kraaikamp, C., Lopuhaä, H. P., & Meester, L. E. (2005). *A Modern Introduction to Probability and Statistics*. Delft: Springer.

Devarasetty, P. C., Burris, M., & Douglass Shaw, W. (2012). The value of travel time and reliability-evidence from a stated preference survey and actual usage. *Transportation Research Part A: Policy and Practice*, *46*(8), 1227–1240. https://doi.org/10.1016/J.TRA.2012.05.002

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1–4.

Euro-Peristat. (2018). *European Perinatal Health Report. Core indicators of the health and care of pregnant women and babies in Europe in 2015.* Retrieved from www.europeristat.com

Faber, M., Bosch, M., Wollersheim, H., Leatherman, S., & Grol, R. (2009). Public reporting in health care: how do consumers use quality-of-care information? A systematic review. *Medical Care*, *47*(1), 1–8. https://doi.org/10.1097/MLR.0b013e3181808bb5

Gaskin, D. J., Hadley, J., & Freeman, V. G. (2001). Are urban safety-net hospitals losing low-risk Medicaid maternity patients? *Health Services Research*, *36*(1 Pt 1), 25–51.

Geodan. (2018). Data & services - Centrale overheid - Accurate reistijdentabel. Retrieved December 12, 2018, from https://www.geodan.nl/nl/producten-en-diensten/centrale-overheid/datasets-en-services/

Gijsen, R., Kommer, G. J., Bos, N., & Van Stel, H. (2010). *Wat is een afdeling Spoedeisende hulp? Volksgezondheid Toekomst Verkenning, Nationaal Kompas Volksgezondheid*. Bilthoven.

Gillham, B. (2008). *Developing a questionnaire* (2nd ed.). A&E Black.

Goodman, L. A. (1961). Snowball Sampling. *The Annals of Mathematical Statistics*, *32*(1), 148–

170.
Gourevitch, R. A., Mehrotra, A., Galvin, G., Karp, M., Plough, A., & Shah, N. T. (2017). How do pregnant women use quality measures when choosing their obstetric provider? *Birth*, *44*(2), 120–127. https://doi.org/10.1111/birt.12273
Hanson, S., & Schwab, M. (1987). Accessibility and Intraurban Travel. *Environment and Planning A: Economy and Space*, *19*(6), 735–748. https://doi.org/10.1068/a190735
He, X. (2011). *Factors Affecting Rural Kentucky Patients Hospital Choice and Bypass Behavior*. University of Kentucky.
Hoogervorst, J. F. (2004, September 24). Regeling van een sociale verzekering voor geneeskundige zorg ten behoeve van de gehele bevolking (Zorgverzekeringswet) in 29763 [Document of government]. *Tweede Kamer Der Staten-Generaal*. https://doi.org/10.1109/ICRA.2011.5979777
Huber, J., Payne, J. W., & Puto, C. (1982). Adding Asymmetrically Dominated Alternatives: Violations of Regularity and the Similarity Hypothesis. *Journal of Consumer Research*, *9*(1), 90. https://doi.org/10.1086/208899
Huber, J., & Zwerina, K. (1996). The Importance of Utility Balance in Efficient Choice Designs. *Journal of Marketing Research*, *33*, 307–317.
IGJ. (2016). *Het resultaat telt. Particuliere klinieken 2016*. Utrecht.
Jacomy, A. (2019). GeoLayout plugin Gephi. Retrieved from https://gephi.org/plugins/#/plugin/geolayout-plugin
Jintanakul, K., & Otto, D. (2009). Factors Affecting Hospital Choice for Rural Iowa Residents. *The Review of Regional Studies*, *39*(2), 171–187.
Jones, A. P., Haynes, R., Sauerzapf, V., Crawford, S. M., Zhao, H., & Forman, D. (2008). Travel time to hospital and treatment for breast, colon, rectum, lung, ovary and prostate cancer. *European Journal of Cancer*, *44*(7), 992–999. https://doi.org/10.1016/J.EJCA.2008.02.001
Joseph, A. E., & Phillips, D. R. (1984). *Accessibility and utilization: geographical perspectives on health care delivery*. London: Harper & Row.
Kadaster. (n.d.). About Kadaster - Kadaster zakelijk. Retrieved April 23, 2019, from https://www.kadaster.com/about-kadaster
Kahle, D., Wickham, H., & Jackson, S. (2019). Package “ggmap.” Retrieved from https://cran.r-project.org/web/packages/ggmap/ggmap.pdf
Kempes, M., & Bunskoek, J. (2019, January 14). Wachttijden in de zorg blijven toenemen: “Patiënt moet ermee leren leven.” *RTL Nieuws*.
KNOV. (2018, November 16). Capaciteitsproblematiek neemt toe en leidt tot nijpende situaties. *Koninklijke Nederlandse Organisatie van Verloskundigen*.
Kolstad, J. T., & Chernew, M. E. (2009). Quality and Consumer Decision Making in the Market for Health Insurance and Health Care Services. *Medical Care Research and Review*, *66*(1), 28–52. https://doi.org/10.1177/1077558708325887
Kommer, G. J., Gijsen, R., De Bruin-Kooistra, M., & Deuning, C. (2017). *Aanbod en bereikbaarheid van de spoedeisende ziekenhuiszorg in Nederland 2017: Analyse gevoelige ziekenhuizen 2017*. https://doi.org/10.21945/RIVM-2017-0108
Kommer, G. J., Gijsen, R., & Giesbers, H. (2019). *Bereikbaarheidsanalyse SEH’s en acute verloskunde bij sluiting van SEH’s van MC Slotervaart en van MC Zuiderzee Ziekenhuis Lelystad*. Bilthoven.

Kommer, G. J., & Mulder, M. (2018). *Referentiekader spreiding en beschikbaarheid ambulancezorg 2018* (Vol. 0128). https://doi.org/10.21945

Kouwenhoven, M., de Jong, G. C., Koster, P., van den Berg, V. A. C., Verhoef, E. T., Bates, J., & Warffemius, P. M. J. (2014). New values of time and reliability in passenger transport in The Netherlands. *Research in Transportation Economics*, *47*, 37–49. https://doi.org/10.1016/J.RETREC.2014.09.017

Kraijesteijn, R. (2016). Postcodetabel van Nederland + SQL Script [Data]. Retrieved from http://www.sqlblog.nl/postcodetabel-nederland-sql-script/

Kroes, E. P., & Sheldon, R. J. (1988). Stated Preference Methods. An Introduction. *Journal of Transport Economics and Policy*, *22*(1), 11–25.

Lane, P. M., & Lindquist, J. D. (1988). Hospital choice: a summary of the key empirical and hypothetical findings of the 1980s. *Journal of Health Care Marketing*, *8*(4), 5–20.

Leensen, R., Poulssen, R., & Weststrate, E. (2018). *Barometer Nederlandse Gezondheidszorg 2018. Rendement zorg stijgt ten koste van personeel*.

Lengton, I. (2019, February 11). "Ambulancetijden op Urk worden overschreden." *De Telegraaf*.

Lin, G., Allan, D. E., & Penning, M. J. (2002). Examining distance effects on hospitalizations using GIS: a study of three health regions in British Columbia, Canada. *Environment and Planning A*, *34*, 2037–2053. https://doi.org/10.1068/a3528

Liu, J., Bellamy, G. R., & McCormick, M. (2007). Patient bypass behavior and critical access hospitals: Implications for patient retention. *Journal of Rural Health*, *23*(1), 17–24. https://doi.org/10.1111/j.1748-0361.2006.00063.x

Louviere, J. J. (1988). *Analyzing Decision Making: Metric Conjoint Analysis*. Newbury Park, Ca: Sage Publication, Inc.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (1998). Combining sources of preference data. *Journal of Econometrics*, *89*(1–2), 197–221. https://doi.org/10.1016/S0304-4076(98)00061

Love, D., & Lindquist, P. (1995). The Geographical Accessibility of Hospitals to the Aged: A Geographic Information Systems Analysis within Illinois. *Health Services Research*, *29*(6), 629–651.

Lux, M. P., Fasching, P. A., Schrauder, · M, Löhberg, · C, Thiel, · F, Bani, · M R, … Goecke, T. W. (2011). The era of centers: the influence of establishing specialized centers on patients' choice of hospital. *Arch Gynecol Obstet*, *283*, 559–568. https://doi.org/10.1007/s00404-010-1398-0

Lynch, B. K. (1996). *Language program evaluation: Theory and practice*. Cambridge: Cambridge University Press.

Marshall, B. S., Javalgi, R. G., & Gombeski, W. R. (1995). Providing services to obstetrical patients: an overview and implications. *Health Marketing Quarterly*, *13*(2), 63–78.

Martin, D., & Williams, H. C. W. L. (1992). Market-Area Analysis and Accessibility to Primary Health-Care Centres. *Environment and Planning A: Economy and Space*, *24*(7), 1009–1019. https://doi.org/10.1068/a241009

Masnick, M., Morgan, D. J., Macek, M. D., Sorkin, J. D., Brown, J. P., Rheingans, P., & Harris, A. D. (2016). Improving the Understanding of Publicly Reported Healthcare-Associated Infection (HAI) Data. *Infection Control & Hospital Epidemiology*, *37*(11), 1349–1354. https://doi.org/10.1017/ice.2016.180

Maurer, M., Firminger, K., Dardess, P., Ikeler, K., Sofaer, S., & Carman, K. L. (2016).

Understanding Consumer Perceptions and Awareness of Hospital-Based Maternity Care Quality Measures. *Health Services Research*, *51*, 1188–1211. https://doi.org/10.1111/1475-6773.12472

Mayer, J. D. (1983). The distance behavior of hospital patients: A disaggregated analysis. *Social Science and Medicine*, *17*(12), 819–827. https://doi.org/10.1016/0277-9536(83)90032-1

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In *Frontiers in Econometrics* (pp. 105–142). Berkeley, CA: Academic Press.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of Applied Econometrics*, *15*, 447–470.

Mediquest. (2019). *Wachttijden in de zorg blijven toenemen*. Utrecht.

Molenaar, D. (2018, November 30). Werkdruk verloskundigen flink toegenomen na sluiting acute verloskunde Hoogeveen en Stadskanaal. *Dagblad van Het Noorden*.

Molin, E. J. E. (2010). Stated Preference Experiments. Retrieved November 21, 2018, from https://wiki.tudelft.nl/bin/view/Organisation/TBM/Catalogue/StatedPreferenceExperiments

Molin, E. J. E. (2016a). Statistical Analysis of Choice Behaviour. Lecture 1: Introduction to experimental designs. [Powerpoint slides]. *Delft University of Technology*.

Molin, E. J. E. (2016b). Statistical Analysis of Choice Behaviour. Lecture 2: Orthogonal designs. [Powerpoint slides]. *Delft University of Technology*.

Molin, E. J. E. (2016c). Statistical Analysis of Choice Behaviour. Lecture 3: Efficient designs. [Powerpoint slides]. *Delft University of Technology*.

Morgan, T. J., Turner, L. W., & Savitz, L. A. (1999). Factors influencing obstetrical care selection. *American Journal of Health Studies*, *15*(2), 100–106.

Mouter, N., & Chorus, C. G. (2016). Value of time – A citizen perspective. *Transportation Research Part A*, *91*, 317–329. https://doi.org/10.1016/J.TRA.2016.02.014

Muller, F. (2019, February 22). Dilemma voor zwangere in Lelystad: thuis bevallen of toch (ver weg) in het ziekenhuis? *Algemeen Dagblad*.

Nederlandse Vereniging van Ziekenhuizen. (2018). *Ziekenhuiszorg in cijfers 2018*. Utrecht. Retrieved from https://www.fwg.nl/

Nesbitt, T. S., Connell, F. A., Hart, L. G., & Rosenblatt, R. A. (1990). Access to obstetric care in rural areas: effect on birth outcomes. *American Journal of Public Health*, *80*(7), 814–818. https://doi.org/10.2105/AJPH.80.7.814

Norton, E. C., & Staiger, D. O. (1994). How Hospital Ownership Affects Access to Care for the Uninsured. *The RAND Journal of Economics*, *25*(1), 171. https://doi.org/10.2307/2555860

NZa. (2015). *Stand van de zorgmarkten 2015*. Retrieved from https://puc.overheid.nl/nza/doc/PUC_3352_22/1/

Oosterom, R. (2018, October 29). Waarom moet het Slotervaartziekenhuis zo snel dicht? *Trouw*.

Oosterom, R., & Van de Wier, M. (2018, October 24). Ziekenhuizen die sluiten: is dat de vrucht van de marktwerking? *Trouw*.

Perined. (2017). *Perinatale Zorg in Nederland 2017*. Utrecht. Retrieved from http://www.perinatreg-data.nl/JB2017/Jaarboek2017.html

Phibbs, C. S., Mark, D. H., Luft, H. S., Peltzman-Rennie, D. J., Garnick, D. W., Lichtenberg, E., & Mcphee, S. J. (1993). Choice of Hospital for Delivery: A Comparison of High-Risk and Low-Risk Women. *Health Services Research*, *28*(2), 201–222. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1069930/pdf/hsresearch00059-0078.pdf

Pilny, A., & Mennicken, R. (2014). Does Hospital Reputation Influence the Choice of Hospital? *Ruhr Economic Papers*, *516*.

Premkumar, D., Jones, D., & Orazem, P. (2016). *Economics Working Papers Hospital Closure and Hospital Choice: How Hospital Quality and Availability will Affect Rural Residents* (No. 16009).

Radcliff, T. A., Brasure, M., Moscovice, I. S., & Stensland, J. T. (2003). Understanding Rural Hospital Bypass Behavior. *The Journal of Rural Health*, *19*(3), 252–259. https://doi.org/10.1111/j.1748-0361.2003.tb00571.x

Ramjerdi, F., Flügel, S., Samstad, H., & Killi, M. (2010). Value of time, safety and environment in passenger transport. *Transportøkonomisk Institutt, Oslo*.

Ravelli, A. C. J., Jager, K. J., De Groot, M. H., Erwich, J. J. H. M., Rijninks-van Driel, G. C., Tromp, M., … Mol, B. W. J. (2011). Travel time from home to hospital and adverse perinatal outcomes in women at term in the Netherlands. *BJOG: An International Journal of Obstetrics and Gynaecology*, *118*(4), 457–465. https://doi.org/10.1111/j.1471-0528.2010.02816.x

RIVM. (2018a). Acute zorg | Regionaal & Internationaal | SEH. Retrieved January 30, 2019, from https://www.volksgezondheidenzorg.info/onderwerp/acute-zorg/regionaal-internationaal/seh

RIVM. (2018b). *Bereikbaarheidsanalyse SEH's en acute verloskunde 2018: Analyse gevoelige ziekenhuizen*.

RIVM. (2018c). *Volksgezondheid Toekomst Verkenning 2018. Trendscenario*. Bilthoven.

RIVM. (2018d). Ziekenhuiszorg | Regionaal & Internationaal | Locaties. Retrieved January 20, 2019, from https://www.volksgezondheidenzorg.info/onderwerp/ziekenhuiszorg/regionaal-internationaal/locaties#node-algemene-en-academische-ziekenhuizen

Robinson, P. C. (1991). *ESP today: A practitioner's guide*. New York: Prentice Hall.

Roh, C.-Y., Lee, K.-H., & Fottler, M. D. (2008). Determinants of Hospital Choice of Rural Hospital Patients: The Impact of Networks, Service Scopes, and Market Competition. *Journal of Medical Systems*, *32*(4), 343–353. https://doi.org/10.1007/s10916-008-9139-7

RTLNieuws. (2019, March 13). Aanrijtijd ambulances flink opgelopen na sluiting IJsselmeerziekenhuizen. *RTL Nieuws*.

RTVDrenthe. (2018, October 13). Laatste weekend verloskunde in Bethesda: "We zijn naar dit moment toegegroeid." *RTV Drenthe*.

Ruwaard, S. (2018). Purchasing healthcare: Beyond getting the financial incentives right. s.l.: Ipskamp.

Savitz, L. A., Ricketts, T. C., & Gesler, W. M. (1994). *The Potential Influence of Maternal Employment on Obstetrical Health Care Seeking Behavior Across the Rural-Urban Continuum*.

Seliger, H. W., & Shohamy, E. G. (1989). *Second language research methods*. Oxford: Oxford University Press.

Sivey, P. (2012). The effect of waiting time and distance on hospital choice for English cataract patients. *Health Economics*, *21*(4), 444–456. https://doi.org/10.1002/hec.1720

Smith Gooding, S. K. (2005). Quality, Sacrifice, and Value in Hospital Choice. *Journal of Hospital Marketing*, *13*(2), 23–42. https://doi.org/10.1300/j043v13n02_03

Smith, M. D., Robson, A. M., Woodward, R. S., Michelman, J. E., Valerius, T. J., & Hong, B. A.

(1985). Geographic access to health care services: the case of maintenance hemodialysis. *American Journal of Kidney Diseases : The Official Journal of the National Kidney Foundation*, *5*(1), 19–26.

Sonneveld, J., & Heida, J. P. (2014, March 12). De buitenpoli is lucratief. *Medisch Contact*.

Stichting Perinatale Registratie Nederland. (2005). *Perinatale Zorg in Nederland 2005*. Utrecht. Retrieved from www.perinatreg.nl

Tai, W.-T. C., Porell, F. W., & Adams, E. K. (2004). Hospital Choice of Rural Medicare Beneficiaries: Patient, Hospital Attributes, and the Patient-Physician Relationship. *Health Services Research*, *39*(6), 1903–1922. https://doi.org/10.1111/j.1475-6773.2004.00324.x

Taylor, J., Zweig, S., Williamson, H., Lawhorne, L., & Wright, H. (1989). Loss of a Rural Hospital Obstetric Unit: A Case Study. *The Journal of Rural Health*, *5*(4), 343–352. https://doi.org/10.1111/j.1748-0361.1989.tb00995.x

The World Bank. (2017). Population density (people per sq. km of land area) | Data. Retrieved November 16, 2018, from https://data.worldbank.org/indicator/EN.POP.DNST?year_high_desc=false

Tokar Erdemir, E., Batta, R., Rogerson, P. A., Blatt, A., & Flanigan, M. (2010). Production, Manufacturing and Logistics Joint ground and air emergency medical services coverage models: A greedy heuristic solution approach. *European Journal of Operational Research*, *207*, 736–749. https://doi.org/10.1016/j.ejor.2010.05.047

Train, K. (2002). *Discrete Choice Methods with Simulation*. New York: Cambridge University Press.

Van Cranenburgh, S. (2016). Kwantitatieve Modellen voor Transport. Lecture 3: Discrete keuzemodellen en het Landelijk modelsysteem (LMS) [Powerpoint slides]. *Delft University of Technology*.

Van Cranenburgh, S. (2017). Travel Behaviour Research. Lecture 7: Latent Class Discrete Choice Models for Travel Behaviour Research [Powerpoint slides]. *Delft University of Technology*.

Van de Wal, H. (2019, April 10). Urk blij met ambulancepost, maar zorgen over de zorg blijven. *De Stentor*.

Van den Berg, M. J., De Boer, D., Gijsen, R., Heijink, R., Limburg, L. C. M., & Zwakhals, S. L. N. (2014). *Zorgbalans 2014. De prestaties van de Nederlandse gezondheidszorg*. Bilthoven.

Van den Berg, M. J., Kringos, D. S., Marks, L. K., & Klazinga, N. S. (2014). The Dutch health care performance report: seven years of health care performance assessment in the Netherlands. *Health Research Policy and Systems*, *12*(1).

Van den Brink, R., & Herderschee, R. (2018, November 15). Alarm verloskundigen: te weinig ziekenhuispersoneel voor bevallingen. *NOS*.

Van den Brink, R., Herderschee, R., & Vleugels, A. (2018, June 2). Personeelstekorten ziekenhuizen nemen dramatisch toe. *NOS*.

Van Lonkhuyzen, L. (2019, March 1). Kinderrijk Urk wacht op calamiteit. *NRC*.

Van Steenbergen, E., & Weeda, F. (2018, December 12). Het wordt reizen voor spoedzorg. *NRC*.

Van Wee, B., & Van Cranenburgh, S. (2017). Substitutability as a concept to understand travel behaviour and its implications. *Proceedings of the BIVEC-GIBERT Transport Research Days 2017: Towards and Autonomous and Interconnected Transport Future*, 1–18.

Van Wee, B., Van Cranenburgh, S., & Maat, K. (2019). Substitutability as a spatial concept to

evaluate travel alternatives.
Varkevisser, M., & Van der Geest, S. A. (2007). Why do patients bypass the nearest hospital? An empirical analysis for orthopaedic care and neurosurgery in the Netherlands. *European Journal of Health and Economy*, *8*, 287–295. https://doi.org/10.1007/s10198-006-0035-0
Varkevisser, M., Van der Geest, S. A., & Schut, F. T. (2009). Quality competition in regulated hospital markets: consumer information and patient choice for angioplasty. *Patient Choice, Competition and Antitrust Enforcement in Dutch Hospital Markets*, *117*, 149.
Victoor, A., Delnoij, D. M., Friele, R. D., & Rademakers, J. J. (2012). Determinants of patient choice of healthcare providers: a scoping review. *BMC Health Services Research*, *12*(1), 272. https://doi.org/10.1186/1472-6963-12-272
Volksgezondheidenzorg.info. (2018a). Ziekenhuiszorg | Cijfers & Context | Aanbod. Retrieved December 14, 2018, from https://www.volksgezondheidenzorg.info/onderwerp/ziekenhuiszorg/cijfers-context/aanbod#node-fusies-tussen-ziekenhuizen
Volksgezondheidenzorg.info. (2018b). Ziekenhuiszorg | Regionaal & Internationaal | Locaties. Retrieved December 12, 2018, from https://www.volksgezondheidenzorg.info/onderwerp/ziekenhuiszorg/regionaal-internationaal/locaties#!node-algemene-en-academische-ziekenhuizen
Volkskrant. (2017, February 23). Typisch Hollands fenomeen uit de gratie: nog maar 13 procent kiest voor thuisbevalling. *De Volkskrant*.
VWS. (2016). *Healthcare in the Netherlands*. The Hague. Retrieved from https://english.zorginstituutnederland.nl/about-us/publications/publications/2016/01/31/healthcare-in-the-netherlands
VWS. (2018). *Beleidsagenda VWS 2019*. Retrieved from https://www.hetzorgverhaal.nl/static/beleidsagendaVWS2019.pdf
Wassenaar, S. (2017, March 23). Geen plek in vijf ziekenhuizen voor zieke Wijchenaar. *De Gelderlander*.
Weeda, F. (2018a, October 11). Groeiende wachtlijsten bij operaties. *NRC*.
Weeda, F. (2018b, October 12). Kiezen op IC: de kanker- of de leverpatiënt? *NRC*.
Wilson, E. B., & Hilferty, M. M. (1931). The Distribution of Chi-Square. *Proceedings of the National Academy of Sciences of the United States of America*, *17*(12), 684–688.
Yeager, D. S., Krosnick, J. A., Chang, L., Javitz, H. S., Levendusky, M. S., Simpser, A., & Wang, R. (2011). Comparing the Accuracy of RDD Telephone Surveys and Internet Surveys Conducted with Probability and Non-Probability Samples. *Public Opinion Quarterly*, *75*(4), 709–747. https://doi.org/10.1093/poq/nfr020
Yin, R. K. (2014). *Case Study Research: Design and Methods*. London, UK: SAGE.
Zelfstandige Klinieken Nederland. (2018). Aangesloten klinieken. Retrieved December 14, 2018, from https://www.zkn.nl/aangesloten-klinieken
Zohrabi, M. (2013). Mixed Method Research: Instruments, Validity, Reliability and Reporting Findings. *Theory and Practice in Language Studies*, *3*(2), 254–262. https://doi.org/10.4304/tpls.3.2.254-262

Appendix A Survey description

This appendix contains the general parts of the preliminary as well as the final survey. The original version (in Dutch) as sent out to the respondents is presented.

Welkom pagina
Welkom

Bedankt dat u de tijd wil nemen om deze vragenlijst in te vullen. De resultaten worden gebruikt bij het schrijven van een scriptie als onderdeel van mijn master aan de Technische Universiteit Delft. Uw hulp wordt dan ook zeer gewaardeerd! Belangrijk om te weten is dat het invullen van de vragenlijst volledig anoniem is. Het verspreiden van de vragenlijst onder bekenden is uiteraard toegestaan.

Het invullen van de vragenlijst zal ongeveer 5 minuten in beslag nemen. Mocht u vragen of opmerkingen hebben, dan kunt u altijd contact met mij opnemen.

Alvast hartelijk bedankt!

Charlotte Giesbers (charlottegiesbers@live.nl)

Pagina 1

Wat is uw geslacht?

a. Man → doorgestuurd naar laatste pagina
b. Vrouw → doorgestuurd naar uitlegpagina

Uitleg pagina
Ik doe onderzoek naar de bereikbaarheid van Verloskundige ziekenhuiszorg in Nederland. Het is echter geen vereiste om ervaring te hebben met verloskundige zorg. U kunt de vragenlijst dus ook invullen als u (nog) nooit zwanger bent geweest, of daar geen plannen toe hebt.

De vragenlijst is wellicht iets anders dan wat u gewend bent qua enquetes. Neemt u daarom even rustig de tijd deze pagina door te lezen. De vragenlijst zelf zal maximaal 5 minuten van uw tijd in beslag nemen. Het eerste deel beslaat een zgn. keuze experiment. U krijgt telkens twee opties te zien, en aan u de vraag om uw favoriete optie te kiezen. Zie onderstaand voorbeeld:

In bovenstaande keuze-optie staan drie elementen centraal:

1. Reiskosten: Dit kan bijvoorbeeld gaan om benzine-kosten, taxi-kosten, of parkeerkosten. Ga ervanuit dat deze kosten voor eigen rekening zijn.
2. Reistijd: Dit is de tijd die het kost om van thuis naar het desbetreffende ziekenhuis te rijden met de auto.
3. Aangeraden: Een bekende van u is reeds in dit ziekenhuis geweest voor een zwangerschapsbehandeling. Deze dame heeft u verteld wat zij ervan vond. 1 ster is de slechtste score, wat betekent dat zij een slechte ervaring heeft met dit ziekenhuis. 5 sterren is de beste score, wat betekent dat zij een erg goede ervaring heeft met dit ziekenhuis. Dit hoeft niks af te doen aan de kwaliteit van zorg. Het gaat om de ervaring van een bekende van u.

Het kan zijn dat u liever thuis zou bevallen. Deze optie valt echter buiten het onderzoeksgebied. Daarom het verzoek toch een keuze te maken. Ga ervan uit dat u de mogelijkheid heeft met de auto naar het ziekenhuis te gaan.

In totaal krijgt u 7 keuzes in het eerste deel. Het tweede en laatste deel bevat vragen over uw persoonlijke situatie.

NB: zoals u kunt zien zijn niet alle elementen die een rol spelen bij de keuze voor een ziekenhuis meegenomen in het voorbeeld. Neemt u daarom aan dat de rest van de factoren voor beide opties gelijk is, voor bijvoorbeeld:

- Uw zorgverzekering heeft met beide ziekenhuizen een contract en vergoedt een gelijk bedrag, ongeacht uw keuze;
- De kwaliteit van zorg in ziekenhuizen is gelijk volgens onafhankelijke websites (zoals Zorgkaart of Kiesbeter);
- Het maakt voor de geboorteplaats op het paspoort van uw kind niet uit welk ziekenhuis u kiest;
- Beide ziekenhuizen bieden dezelfde zorgfaciliteiten (bijvoorbeeld voor wat betreft eventuele pijnstilling privebadkamers, een bevalkruk, etc.);
- Beide ziekenhuizen geven u evenveel ruimte voor inspraak in de behandeling, zoals beslissingen over pijnstilling;
- …

Appendix B Standard errors and significance of estimations

For the estimation of model parameters, it is key to check for significance. This appendix contains a short explanation on how to derive whether or not parameters are significant. It helps in understanding why a researcher should try to achieve small standard errors, or why this is done in this research project. If one is looking for more background information, the book A Modern Introduction to Probability and Statistics by Dekking, Kraaikamp, Lopuhaä and Meester is recommended (2005).

When estimating models, it is assumed there is a parameter β that accounts for the mean in the population. So, when drawing a sample, this gives an indirect measurement of the sample mean of this β. The objective then is to find "the set of parameters that make the data the most likely" (Chorus, 2018, p. 33).

To test to what extent an estimated parameter $\hat{\beta}$ is a valid representation of the population parameter β, one can use a test-statistic called the t-value. It is assumed that standard errors of $\hat{\beta}$ are normally distributed for a sample bigger than 30, which is the case in this research (Chorus, 2018). A t-test is used to test a null hypothesis in the following form:

$$H_0 : \beta = \beta_0 = 0$$

So, in this case, it means that the null-hypothesis means the parameter for the population is equal to 0, and the t-test will help derive the probability that this is true. First one needs to derive the standard error, as shown in equation (8).

$$se_{b\,i} = \frac{s_e}{\sqrt{\left(1 - R^2_{X_i G_k}\right) * s^2_{X_i} * (N-1)}} \tag{8}$$

In which s_e is the standard error of the estimate, $R^2_{X_i G_k}$ is the explained variance of all other variables G_k, so therefore $\left(1 - R^2_{X_i G_k}\right)$ equals the unexplained variance. $S^2_{X\,i}$ is the variance of predictor X_i and N denotes the number of observations (Molin, 2016a). There are a few steps to be taken before one can calculate se_{b_i}.

First of all, one needs the total sum of squares related to the variance of Y, which is the total variance. Assuming Y is the estimated regression parameter, this is the sum of the squares of the difference between the actual value for Y for case i. It can be calculated by adding the sum of squares of the regression variance to the sum of squares of the error variance, as presented in equation (9). In which $\bar{Y}$ is the mean of Y, Y_i is the value of for Y for case i and $\widehat{Y_\iota}$ is the predicted value for X_i by regression.

$$\sum (Y_i - \bar{Y})^2 = \sum \left(\hat{Y}_i - \bar{Y}\right)^2 + \sum \left(Y_i - \hat{Y}_i\right)^2 \tag{9}$$

Now, the explained variance $R^2_{X_i G_k}$ can be obtained using equation (10).

$$R^2_{X_i G_k} = \frac{\sum\left(\hat{Y}_i - \bar{Y}\right)^2}{\sum(Y_i - \bar{Y})^2} \tag{10}$$

The last input parameter needed for the se_{b_i}, is s_e or the standard error of the estimate. To derive s_e, take the square root of the error as shown in equation (11) in which k equals the number of parameters.

$$s_e = \sqrt{\frac{\sum\left(Y_i - \hat{Y}_i\right)^2}{(N - k - 1)}} \tag{11}$$

Based on this standard error, the t-value test statistic can be calculated using equation (12) (Dekking et al., 2005).

$$t_{b_i} = \frac{\hat{\beta} - \beta_0}{se_{b_i}} = \frac{\hat{\beta}}{se_{b_i}} \tag{12}$$

The obtained t-value t_{b_i} is then tested against a threshold T . This threshold is chosen by the researcher based on the desired confidence level or significance level α (Dekking et al., 2005). The rule of thumb is $\alpha = 0.05$, which leads to a threshold of 1.96 (Chorus, 2018). However, the higher the t-value, the better. The t-test of t_{b_i} against T results in a p-value, as shown in equation (13). Colloquially speaking, p represents the probability that null hypothesis is true, or that the population value β is equal to 0 (Chorus, 2018).

$$p = P(t_{bi} \geq T) \tag{13}$$

Consequently, ideally the p-value should be as close to 0 as possible. This implies high t-values are desired, as this leads to highly significant $\hat{\beta}$ parameters for the sample. To obtain high t-values, the standard errors should be as low as possible.

Appendix C Pilot survey and prior derivation

To be able to use efficient designs, priors are obtained based on a pilot survey among 33 respondents. Note that these respondents are not randomly chosen but are all filled in by women known by the researcher. Therefore, the obtained priors may not be a correct representation of the population.

The choice set used in this pilot study has been constructed based on a fractional factorial design, using Ngene. However, when using this type of designs on unlabelled alternatives, dominant alternatives are very likely to be included. As pointed out by Huber and Zwerina (1996), dominant alternatives should be avoided, as they provide no information about parameters. An alternative is viewed as “dominant if it is better than (or equal to) any other alternative in the choice set with respect to all alternatives.” (Bliemer, Rose, & Chorus, 2017, p. 84). The presence of dominant alternatives can lead to biased parameter estimates (Huber, Payne, & Puto, 1982).

The orthogonal design for the different choice sets has been generated using Ngene, with the syntax as shown in Script 1. The outcome for the design of the first run can be seen in Table C.1.

Script 1 Orthogonal sequential design - Ngene

```
design
;alts = alt1, alt2
;rows = 9
;orth = seq
;model:
U(alt1) = bt * time[10,20,30] + bc * costs[3.50, 6.00, 8.50] + br * recom[2, 3, 4]/
U(alt2) = bt * time + bc * costs + br * recom
$
```

Table C.1 Choice sets for run 1

Choice situation	alt1.time	alt1.costs	alt1.recom	alt2.time	alt2.costs	alt2.recom
1	10	3.5	2	10	6	3
2	30	6	2	30	3.5	4
3	20	8.5	2	20	6	4
4	30	8.5	3	10	3.5	2
5	20	3.5	3	30	6	2
6	10	6	3	30	8.5	3
7	20	6	4	10	8.5	4
8	10	8.5	4	20	8.5	2
9	30	3.5	4	20	3.5	3

When zooming in on the different choice sets, it is easy to identify dominant alternatives. For example, the second choice set would look as previewed in Figure C.1. Because the travel time to both hospitals is 30 minutes, the costs to get to Hospital A are €6.00 and higher than Hospital B’s

€3.50, and Hospital A's recommendation rating is only 2/5 while Hospital B scores 4/5, there is no reason a fully rational respondent would choose Hospital A. In other words, Hospital B is dominant over Hospital A in choice set 2.

Figure C.1 Choice set 2 of run 1

In order to check for dominance, it is possible to use hypothetical parameter values. In case of an expected positive impact on utility, one can use $\beta = 1$. Then for a negative impact, a value of $\beta = -1$ is suitable (Bliemer et al., 2017). For the utility of the hospital, higher travel time and travel costs are expected to have a negative impact, while a higher recommendation score is supposed to have a positive impact (Pilny & Mennicken, 2014) The utility function, as has been defined in the syntax as well, would now look as equation (14).

$$V_{hospital} = -1 * Traveltime + -1 * Travelcosts + 1 * Recommended \qquad (14)$$

When taking the definition for dominance into account, run 1 contains a dominant alternative for five of the nine choice sets. This is shown in Table C.2.

Table C.2 Dominance check for run 1

Choice Situation	Score1 Time	Score1 Costs	Score1 recom	Score2 time	Score2 Costs	Score2 recom	Alt 1 dominant?	Alt 2 dominant?
1	-10	-3.5	2	-10	-6	3	**FALSE**	**FALSE**
2	-30	-6	2	-30	-3.5	4	**FALSE**	**TRUE**
3	-20	-8.5	2	-20	-6	4	**FALSE**	**TRUE**
4	-30	-8.5	3	-10	-3.5	2	**FALSE**	**FALSE**
5	-20	-3.5	3	-30	-6	2	**TRUE**	**FALSE**
6	-10	-6	3	-30	-8.5	3	**TRUE**	**FALSE**
7	-20	-6	4	-10	-8.5	4	**FALSE**	**FALSE**
8	-10	-8.5	4	-20	-8.5	2	**TRUE**	**FALSE**
9	-30	-3.5	4	-20	-3.5	3	**FALSE**	**FALSE**

As dominant alternatives provide no information for taste parameters and may as well be deleted from choice sets, this first orthogonal design is not very useful. Therefore, Script 1 is rerun several times to see if it is possible to get 'better' designs, in other words, designs that contain a fewer number of dominant alternatives. The results of the first 10 runs can be found in Table C.3. As can be seen, some runs score way worse than others. However, all runs contain at least three dominant alternatives in their choice sets.

Table C.3 Dominance in the first 10 runs of Script 1

Run	Dominance Alt 1	Dominance Alt 2	Ratio
1	3	2	**56%**
2	2	2	**44%**
3	2	2	**44%**
4	2	2	**44%**
5	2	1	**33%**
6	2	2	**44%**
7	2	2	**44%**
8	0	3	**33%**
9	3	3	**67%**
10	2	2	**44%**

For the pilot, design number 5 is chosen. The choice sets in this design are shown in Table C.4. As can be seen, in choice situation 2 the first alternative is dominant while for choice situation 6 and 7 the second alternative is dominant. These are kept in to make sure the way a SC experiment works is understood by all respondents. Usually, dominant alternatives should be deleted as it may lead to respondents not taking the survey seriously. But as all the pilot respondents are closely related, it is certain they will fill out the entire survey anyways.

Table C.4 Choice sets for run 5

Choice situation	alt1.time	alt1.costs	alt1.recom	alt2.time	alt2.costs	alt2.recom
1	10	3.5	2	10	8.5	4
2	30	6	2	10	6	3
3	20	8.5	2	30	6	2
4	30	8.5	3	10	3.5	2
5	20	3.5	3	20	6	4
6	10	6	3	20	8.5	2
7	20	6	4	30	8.5	3
8	10	8.5	4	30	3.5	4
9	30	3.5	4	20	3.5	3

The survey description as presented in Appendix A and the choice sets are added to the pilot survey using Google Forms. An overview of the output of the SC pilot is visually shown in Figure C.2. As can be seen, every respondent understood the SC experiment because choice set 2, 6 and 7 all have either only A or only B as their response. Therefore, it is assumed the description of the pilot survey is easy to understand, not too long and correctly formulated. Moreover, the other choice sets did not have any alternative that was chosen by all 33 respondents. However, in choice set 8 and 9, Hospital A is chosen by the majority of respondents. This does not necessarily mean this will lead to trouble later on.

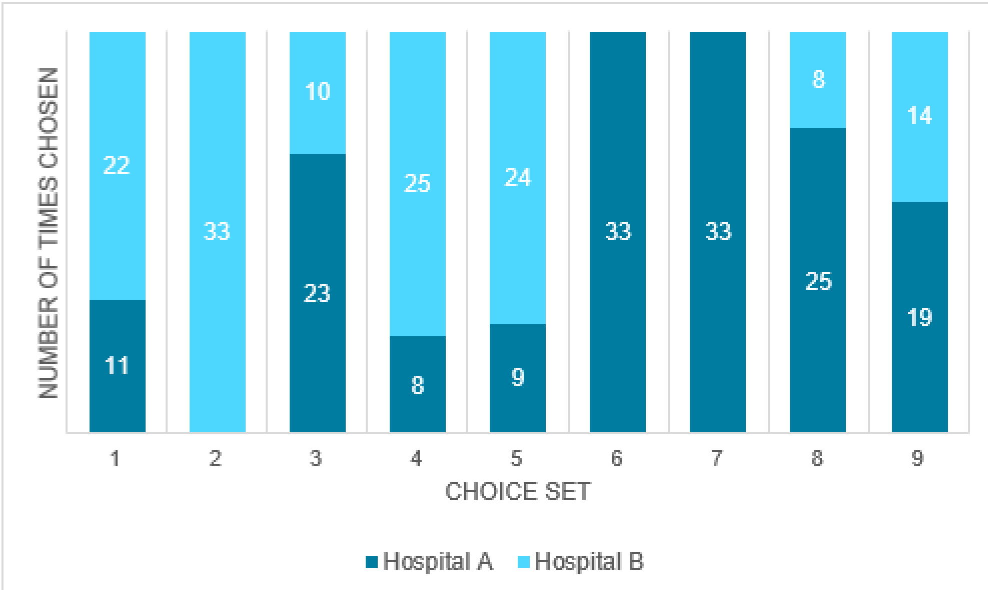


Figure C.2 Responses to pilot SC experiment

Based on the outcomes of the pilot survey, it is possible to estimate prior values for the different parameters. However, to make it possible to use the data obtained from the spreadsheet of Google Forms in PythonBiogeme, a bit of data preparation is needed. Therefore, the following Script 2 is run in R. It makes sure all dominant alternatives are deleted as well.

Script 2 Google Forms to PythonBiogeme data file - R

```r
#Charlotte Giesbers (Delft University of Technology)
#April 2, 2019
#Version 1.0
#****************************************************************************************************

#The objective of this script is to prepare a Google Forms output spreadsheet for usage in
#PythonBiogeme.
#****************************************************************************************************

#Install required packages
#install.packages("dyplr") #only run once
library("dyplr")

#Open file containing Zipcodes for the origins
Path <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
Pilot <- read.csv2(file.path(Path, "FormulierReacties.csv"), stringsAsFactors = FALSE)

#Delete first 2 columns with the timestamp and the respondents sex
Pilot <- Pilot[ , -c(1,2)]

#Delete last two columns
Pilot <- Pilot[ , -c(10,11)]

#Set column names to choice set numbers
colnames(Pilot) <- c("CS1", "CS2", "CS3", "CS4", "CS5", "CS6", "CS7", "CS8", "CS9")

#create a vector containing all choices
PilotVector <- as.vector(t(Pilot))

#Create a new dataframe that contains ID numbers and Choiceset numbers
NmbofResp <- nrow(Pilot)
ID <- rep(1:NmbofResp, each=9)
CS <- rep(1:9, times=NmbofResp)
OutputTable <- cbind(ID, CS)

 #Now convert all "Ziekenhuis A" to a 1 and all "Ziekenhuis B" to a 2 and add these to the table
ZiekenhuisConv <- function(x) {
  switch(x,
         "Ziekenhuis A" = 1,
         "Ziekenhuis B" = 2)
}

Choice <- sapply(PilotVector, ZiekenhuisConv)
OutputTable <- cbind(OutputTable, Choice)
rownames(OutputTable) <- c()

#Pythonbiogeme requests all alternative values to be in the data set as well
#So first, import the table that contains the choice set
ChoiceSets <- read.csv2(file.path(Path, "ChoiceSetsPilot.csv"), stringsAsFactors = FALSE)

#rename the first column of the ChoiceSets table to match the OutputTable
colnames(ChoiceSets)[1] <- "CS"

#rename the column names to match PythonBiogeme restrictions
colnames(ChoiceSets)[2:7] <- c("ALT1T", "ALT1C", "ALT1R", "ALT2T", "ALT2C", "ALT2R")

#Add the Choice Sets repeatedly to the outputtable (CS makes it work automatically)
OutputTable <- cbind(OutputTable, ChoiceSets)

#Delete one of the columns containing CS as we only need 1
OutputTable <- OutputTable[, -4]

#Finally, delete choice sets with dominant alternatives
#First, check for dominance by averaging all choices.
C4D <- OutputTable %>%
  group_by(CS) %>%
  summarise(AV = mean(Choice))

#all rounded numbers indicate dominance, so we want a vector that does not contain 1 or 2
NoDom <- c(which(C4D$AV != 1 & C4D$AV != 2))
print(NoDom)

#Delete the dominant choices from the data (done by hand based on "NoDom"!)
OutputTable <- subset(OutputTable, CS == 1 | CS == 5 | CS == 6 | CS == 7 | CS == 8 | CS == 9)

#Save outputtable so it can be used in PythonBiogeme (so in a .dat file!)
write.table(OutputTable,
            file.path(Path, "PilotPythonBiogeme.dat"),
            quote = FALSE,
            sep = "\t",
            row.names = FALSE)

```

Now that the data is prepared, one needs to define a python file that contains the model, to serve as input for PythonBiogeme. The model can be viewed in Script 3.

Script 3 MNL model definition for pilot - PythonBiogeme

```
#Charlotte Giesbers (Delft University of Technology)
#April 2, 2019
#Version 1.0
#**************************************************************************************************

#The objective of this script is to define a MNL model for the PilotPythonBiogeme.dat file.
#**************************************************************************************************

#Import required packages
from headers import *
from biogeme import *
from loglikelihood import *
from statistics import *

#Parameters to be estimated (Name, starting value, lower bound, upper bound, 1=fixed)
B_TT = Beta('B_TT', 0, -1000, 1000, 0)
B_TC = Beta('B_TC', 0, -1000, 1000, 0)
B_R  = Beta('B_R', 0, -1000, 1000, 0)

#Utility functions
V1 = B_TT * ALT1T + B_TC * ALT1C + B_R * ALT1R
V2 = B_TT * ALT2T + B_TT * ALT2C + B_R * ALT2R

#Associate utility functions with the numbering of alternatives
V = {1: V1,
    2: V2}

#Availaility of alternatives
AV1 = 1
AV2 = 1

av = {1: AV1,
      2: AV2}

#Choice model is a logit with availability conditions
logprob = bioLogLogit(V, av, Choice)

#defines an iterator on the data
rowIterator('obsIter')

#Define the likelihood function for the estimation
BIOGEME_OBJECT.ESTIMATE = Sum(logprob, 'obsIter')

#Statistics
nullLoglikelihood(av, 'obsIter')
choiceSet = [1,2]
cteLoglikelihood(choiceSet, Choice, 'obsIter')
availabilityStatistics(av, 'obsIter')
```

As can be seen, the same column names have been used in Script 2 and Script 3, as these files are combined automatically by PythonBiogeme. Running the scripts in this program gives the output as shown in Table C.5. As can be seen, the value estimation for β_{TC} is insignificant while β_R and β_{TT} are both significant on a 99% confidence scale (please see Appendix C for more background information on standard significance).

Table C.5 Estimation report pilot MNL model

Name	Value	Std err	t-test	p-value
β_R	0.736	0.185	3.99	0.00
β_{TC}	-0.0599	0.0277	-2.16	0.03
β_{TT}	-0.0749	0.0149	-5.03	0.00
			Number of estimated parameters:	3
			Sample size:	198
			Excluded observations:	0
			Init log likelihood:	-137.243
			Final log likelihood:	-121.339
			Likelihood ratio test for the initial model:	31.808
			Rho-square for the initial model:	0.116

All three βs are of the expected sign. To get an insight in the effects of the different parameters on the utility functions the parameter values are multiplied by the attribute level range:

$$\beta_R * (\max_R - \min_R) = 0.736 * (4 - 2) = +1.472$$

$$\beta_{TC} * (\max_{TC} - \min_{TC}) = -0.0599 * (8.50 - 3.50) = -0.2995$$

$$\beta_{TT} * (\max_{TT} - \min_{TT}) = -0.0749 * (30 - 10) = -1.498$$

The utility range of the parameter for travel time is the most important, which was expected. However, the impact of β_R is bigger than expected. Apparently, recommendation values are viewed as important in the pilot. As expected, the impact of β_{TC} is smallest.

Because of the lower significance of the parameter estimate β_{TC}, it would be imprudent to use this value as a prior. Therefore, it is decided to use a Bayesian distribution to create an efficient design for the final survey. Ngene can easily handle this by adding the expected value and the standard deviation. The standard deviation can be calculated as follows, and in order to implement this in Ngene, Script 4 is run.

$$\sigma_{\beta_{TC}} = se_{\beta_{TC}} * \sqrt{n} = 0.0277 * \sqrt{198} = 0.389774$$

Script 4 Bayesian efficient design including pilots' priors - Ngene

```
design
;alts = alt1, alt2
;rows = 9
;eff = (mnl, d, mean)
;model:
U(alt1) = bt[-0.0749] * time[10,20,30] +
          bc[(n,-0.0599, 0.389774)] * costs[3.50, 6.00, 8.50] +
          br[0.736] * recom[2, 3, 4]/
U(alt2) = bt * time + bc * costs + br * recom
$
```

As can be seen, the estimated β values for travel time and recommendation have been used. A normal distribution is used for β_{TC}, using the estimated pilot parameter value as the mean and the calculated value for the standard distribution as input. The number of rows is set to 9. It could have been done by 6, but it is expected the efficient design will still contain some dominant alternatives in the choice sets. As these dominant alternatives will be removed, 9 rows have been designed. This design is a d-efficient design, which is why Ngene will run indefinitely while it tries to find the lowest D-error. Therefore, the run has to be stopped manually. After evaluating 80,000 values, the D-error of evaluation number 1876 was still the lowest, so the run was determined.

The output values are presented in the following tables. As can be seen in Table C.6, the D-error found is 0.0440, which is very close to 0. Then when looking at Table C.7, the output is as expected. The Sp estimates give an indication of the number of respondents required to be able to estimate reliable parameter values. β_{TC} or bc shows the highest value, which implies Ngene recognized the insignificance of the parameter in the pilot.

Table C.6 Output Bayesian Mean D-efficient evaluation 1876

	Fixed	Mean	Std dev.	Median	Minimum	Maximum
D error	0.0331	0.0440	0.0166	0.0373	0.0331	0.1376
A error	0.1428	0.1864	0.0721	0.1545	0.1426	0.5441
B estimate	72.7533	62.2836	11.1454	66.0066	25.3447	73.2754
S estimate	45.9006	99.9506	527.6641	5.0645	2.6661	5818.6545

Table C.7 Output Bayesian Mean D-efficient evaluation 1876 - 2

Prior	bt	bc	br
Fixed prior value	-0.0749	-0.0599	0.736
Sp estimates	2.52697	45.90065	2.70884
Sp t-ratios	1.23298	0.28930	1.19087
Sb mean estimates	3.40612	98.91326	3.25421
Sb mean t-ratios	1.10226	0.96886	1.11191

Concludingly, the design as created by evaluation 1876 in the MNL Bayesian Mean D-efficient design is suitable for usage.

Appendix D Final survey questions list

The first part of this appendix contains the seven choice sets of the SC experiment, while the second part contains the general personal questions that were added to the survey. The survey was conducted in Dutch so the rest of this appendix is in Dutch as well. Google Forms was used to conduct the survey as it is user-friendly and allows the researcher to access the results in a simple spreadsheet format.

Nogmaals:
Het betreft een hypothetisch onderzoek. Probeer dus de vragen te beantwoorden met de informatie die gegeven wordt. Probeer de ideeën die u heeft, over bijvoorbeeld het ziekenhuis in uw buurt, even te laten varen. Neem aan dat de factoren die niet beschreven staan voor beide ziekenhuizen gelijkwaardig zijn.

Welk ziekenhuis zou uw voorkeur hebben? (1/7)

Welk ziekenhuis zou uw voorkeur hebben? (2/7)

Welk ziekenhuis zou uw voorkeur hebben? (3/7)

	Ziekenhuis A	Ziekenhuis B
Reistijd (minuten)	10	20
Kosten (€)	6,00	6,00
Aangeraden	★★★☆☆	★★★★☆

Welk ziekenhuis zou uw voorkeur hebben? (4/7)

	Ziekenhuis A	Ziekenhuis B
Reistijd (minuten)	20	30
Kosten (€)	6,00	3,50
Aangeraden	★★★★☆	★★★★☆

Welk ziekenhuis zou uw voorkeur hebben? (5/7)

	Ziekenhuis A	Ziekenhuis B
Reistijd (minuten)	10	30
Kosten (€)	8,50	6,00
Aangeraden	★★★★☆	★★☆☆☆

Welk ziekenhuis zou uw voorkeur hebben? (6/7)

Welk ziekenhuis zou uw voorkeur hebben? (7/7)

Bedankt voor uw medewerking! Nu volgen nog enkele vragen die betrekking hebben op uw persoonlijke situatie. Het beantwoorden van deze vragen draagt bij aan de validiteit van het onderzoek.

Wat is uw leeftijd?

____

Bent u het afgelopen jaar in het ziekenhuis geweest?
Let op: he tgaat hierbij om een ziekenhuisbezoek voor uzelf. Dus niet het bezoeken van een bekende oid.

- o Ja
- o Nee
- o Hier geef ik liever geen antwoord op

Bent u zelf wel eens bevallen?

- o Ja
- o Nee
- o Hier geef ik liever geen antwoord op

(Indien 'Ja' op vorige vraag) Op welke locatie vond uw laatste bevalling plaats?

- Thuis
- In een verloskunde kliniek
- In een ziekenhuis
- Hier geef ik liever geen antwoord op
- Anders …

Wat is uw hoogst genoten (of huidige) opleiding?

- Bassischool
- Middelbare school: MAVO, VMBO
- Middelbare school: HAVO, VWO
- MBO
- HBO
- WO

Hoe zou u uw dagelijkse bezigheid omschrijven?

- Ik werk full-time
- Ik werk part-time
- Student
- Gepensioneerd
- Ik heb momenteel geen baan
- Hier geef ik liever geen antwoord op
- Anders …

Wat is uw jaarlijkse netto-inkomen?

- Minder dan €10,000
- €10,001 - €20,000
- €20,001 - €30,000
- €30,001 - €40,000
- €40,001 - €50,000
- Meer dan €50,001
- Hier geef ik liever geen antwoord op

Bent u in het bezit van een auto?

- Ja
- Nee

Wat zijn de vier cijfers van uw postcode?

____

Heel erg bedankt voor uw medewerking! Mocht u nog dames kennen die eventueel bereid zouden zijn om de vragenlijst in te vullen, wordt het delen van de vragenlijst erg gewaardeerd. Mocht u geïnteresseerd zijn in mijn scriptie, dan kunt u hier uw emailadres achterlaten. Ik zal u dan na mijn afstuderen het rapport toesturen.

Appendix E Data preparation using R

This appendix contains the script that is used for the data preparation of the SC experiment. Script 5 is self-explanatory.

Script 5 Data preparation form Google Forms to PythonBiogeme - R

```r
#Charlotte Giesbers (Delft University of Technology)
#April 2, 2019
#Version 2
#*************************************************************************************************

#The objective of this script is to prepare a Google Forms output spreadsheet for usage in
#PythonBiogeme. It also serves as a data preparation script, deleting incorrect or incomplete
#responses.
#*************************************************************************************************

#Install required packages
#install.packages("dplyr") #only run once
#install.packages("tidyverse") #only run once

#Open file containing Zipcodes for the origins
Path <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
StatedChoice <- read.csv2(file.path(Path, "AntwoordenSurvey.csv"), stringsAsFactors = FALSE)

#Delete the men from the respondents group
StatedChoice <- StatedChoice[grep("Man", StatedChoice$Wat.is.uw.geslacht., invert = TRUE), ]

#Delete first 2 columns with the timestamp and the respondents sex as these are no longer needed
StatedChoice <- StatedChoice[ , -c(1,2)]

#Delete columns with demographics, as these are not needed for Biogemes DCM
StatedChoice <- StatedChoice[ , -c(8:16)]

#Set column names to choice set numbers
colnames(StatedChoice) <- c("CS1", "CS2", "CS3", "CS4", "CS5", "CS6", "CS7")

#Check if no respondent has chosen only hospital A or B
C4A <- c(which(StatedChoice$CS1 == "Ziekenhuis A" &
               StatedChoice$CS2 == "Ziekenhuis A" &
               StatedChoice$CS3 == "Ziekenhuis A" &
               StatedChoice$CS4 == "Ziekenhuis A" &
               StatedChoice$CS5 == "Ziekenhuis A" &
               StatedChoice$CS6 == "Ziekenhuis A" &
               StatedChoice$CS7 == "Ziekenhuis A"))
C4B <- c(which(StatedChoice$CS1 == "Ziekenhuis B" &
               StatedChoice$CS2 == "Ziekenhuis B" &
               StatedChoice$CS3 == "Ziekenhuis B" &
               StatedChoice$CS4 == "Ziekenhuis B" &
               StatedChoice$CS5 == "Ziekenhuis B" &
               StatedChoice$CS6 == "Ziekenhuis B" &
               StatedChoice$CS7 == "Ziekenhuis B"))
#Returns both empty vectors, which means no respondent solely one response, either A or B

#create a vector containing all choices
StatedChoiceVector <- as.vector(t(StatedChoice))

#Create a new dataframe that contains ID numbers and Choiceset numbers
NmbofResp <- nrow(StatedChoice)
NmbofCS <- ncol(StatedChoice)
ID <- rep(1:NmbofResp, each=NmbofCS)
CS <- rep(1:NmbofCS, times=NmbofResp)
OutputTable <- cbind(ID, CS)

#Now convert all "Ziekenhuis A" to a 1 and all "Ziekenhuis B" to a 2 and add these to the table
ZiekenhuisConv <- function(x) {
  switch(x,
         "Ziekenhuis A" = 1,
         "Ziekenhuis B" = 2)
}

```

```r
Choice <- sapply(StatedChoiceVector, ZiekenhuisConv)
OutputTable <- cbind(OutputTable, Choice)
rownames(OutputTable) <- c()

#**************************************************************************************************
#Pythonbiogeme requests all alternative values to be in the data set as well
#So first, import the table that contains the choice set
ChoiceSets <- read.csv2(file.path(Path, "ChoiceSetsFinal.csv"), stringsAsFactors = FALSE)

#rename the first column of the ChoiceSets table to match the OutputTable
colnames(ChoiceSets)[1] <- "CS"

#rename the column names to match PythonBiogeme restrictions
colnames(ChoiceSets)[2:7] <- c("ALT1T", "ALT1C", "ALT1R", "ALT2T", "ALT2C", "ALT2R")

#Add the Choice Sets repeatedly to the outputtable (CS makes it work automatically)
OutputTable <- cbind(OutputTable, ChoiceSets)

#Delete one of the columns containing CS as we only need 1
OutputTable <- OutputTable[, -4]

#**************************************************************************************************
#Delete choice sets with dominant alternatives
#First, check for dominance by averaging all choices. "dplyr" package is required.
library("dplyr")
C4D <- OutputTable %>%
  group_by(CS) %>%
  summarise(AV = mean(Choice))

#all rounded numbers indicate dominance, so we want a vector that does not contain 1 or 2
NotDom <- c(which(C4D$AV != 1 & C4D$AV != 2))
print(NotDom)

#The output for 'NotDom' shows dominance in choice set 5, which is unexpected. It also shows
#that in choice set 7, not every respondent chose hospital B. The respondents that chose hospital
#A will be deleted as this alternative was strictly dominant.
Mistake <- c(which(OutputTable$CS == 7 & OutputTable$Choice == 1))
print(OutputTable[c(Mistake), "ID"])

#Respondents with ID 24 and 27 made a mistake when filling out the survey, so these responses
#will be deleted.
OutputTable <- subset(OutputTable, ID != 24 & ID != 127)

#Rerun the dominance check to see if this worked well
C4D2 <- OutputTable %>%
  group_by(CS) %>%
  summarise(AV = mean(Choice))
NotDom2 <- c(which(C4D2$AV != 1 & C4D2$AV != 2))
print(NotDom2)

#Delete the dominant choices from the data (done by hand based on 'NotDom'!)
OutputTable <- subset(OutputTable, CS == 1 | CS == 2 | CS == 3 | CS == 4 | CS == 6)

#Save outputtable so it can be used in PythonBiogeme (so in a .dat file!)
write.table(OutputTable,
            file.path(Path, "FinalSurveySC.dat"),
            quote = FALSE,
            sep = "\t",
            row.names = FALSE)
```

Appendix F List of acute obstetrics locations

This appendix contains the full list of hospitals that have AO care available, updated in December 2018 based on data provided by RIVM (2018d). In order to be marked as a hospital that provides AO care, a hospital needs to meet the following three requirements:

1. AO 24 hours a day 7 days a week,
2. Presence of clinical obstetrician or gynaecologist, and
3. Gynaecologist, paediatrician, anaesthesiologist, nurse anaesthetist and operating room available within 30 minutes (Kommer et al., 2017).

The addresses of the 78 locations were provided by personal communication (H. Giesbers, February 6, 2019). The full list can be found in Table F.1.

Table F.1 List of AO locations updated December 2018 (adapted from RIVM)

Nr	Hospital Name	Address	Place	Zip code
1	Noordwest Ziekenhuisgroep	Wilhelminalaan 12	Alkmaar	1815 JD
2	Ziekenhuisgroep Twente	Zilvermeeuw 1	Almelo	7609 PP
3	Flevoziekenhuis	Hospitaalweg 1	Almere	1315 RA
4	Meander Medisch Centrum	Maatweg 3	Amersfoort	3813 TZ
5	BovenIJ Ziekenhuis	Statenjachtstraat 1	Amsterdam	1034 CS
6	OLVG	Jan Tooropstraat 164	Amsterdam	1061 AE
7	OLVG	Oosterpark 9	Amsterdam	1091 AC
8	VU Medisch Centrum	de Boelelaan 1117	Amsterdam	1081 HV
9	Academisch Medisch Centrum	Meibergdreef 9	Amsterdam	1105 AZ
10	Gelre Ziekenhuizen	A Schweitzerlaan 31	Apeldoorn	7334 DZ
11	Rijnstate Ziekenhuis	Wagnerlaan 55	Arnhem	6815 AD
12	Wilhelmina Ziekenhuis Assen	Europaweg Zuid 1	Assen	9401 RK
13	Bravis Ziekenhuis	Boerhaaveplein 1	Bergen Op Zoom	4624 VT
14	Pantein	Dokter Kopstraat 1	Beugen	5835 DV
15	Rode Kruis Ziekenhuis	Vondellaan 13	Beverwijk	1942 LE
16	Tergooi	Rijksstraatweg 1	Blaricum	1261 AN
17	Amphia Ziekenhuis	Langendijk 75	Breda	4819 EV
18	IJsselland Ziekenhuis	Prins Constantijnweg 2	Capelle aan de Ijssel	2906 ZC
19	Stichting Reinier Haga Groep	Reinier de Graafweg 3	Delft	2625 AD
20	Noordwest Ziekenhuisgroep	Huisduinerweg 3	Den Helder	1782 GZ
21	Deventer Ziekenhuis	Nico Bolkesteinlaan 75	Deventer	7416 SE
22	Stichting het Van Weel-Bethesda Ziekenhuis	Stationsweg 22	Dirksland	3247 BW
23	Slingeland Ziekenhuis	Kruisbergseweg 25	Doetinchem	7009 BL
24	Albert Schweitzer Ziekenhuis	A Schweitzerplaats 25	Dordrecht	3318 AT
25	Nij Smellinghe	Compagnonsplein 1	Drachten	9202 NN
26	Ziekenhuis Gelderse Vallei	Willy Brandtlaan 10	Ede	6716 RP
27	Catharina Ziekenhuis	Michelangelolaan 2	Eindhoven	5623 EJ

28	Treant Zorggroep	Boermarkeweg 60	Emmen	7824 AA
29	Medisch Spectrum Twente	Koningplein 1	Enschede	7512 KZ
30	St. Anna Zorggroep	Bogardeind 2	Geldrop	5664 EH
31	Admiraal De Ruyter Ziekenhuis	s Gravenpolderseweg 114	Goes	4462 RA
32	Rivas Zorggroep	Banneweg 57	Gorinchem	4204 AA
33	Groene Hart Ziekenhuis	Bleulandweg 10	Gouda	2803 HH
34	Universitair Medisch Centrum Groningen	Hanzeplein 1	Groningen	9713 GZ
35	Martini Ziekenhuis	Van Swietenlaan 1	Groningen	9728 NT
36	Spaarne Gasthuis	Boerhaavelaan 22	Haarlem	2035 RC
37	Saxenburgh Groep	Jan Weitkamplaan 4a	Hardenberg	7772 SE
38	Ziekenhuis St. Jansdal	Weth Jansenlaan 90	Harderwijk	3844 DG
39	De Tjongerschans	Thialfweg 44	Heerenveen	8441 PW
40	Zuyderland	H Dunantstraat 5	Heerlen	6419 PC
41	Elkerliek Ziekenhuis	Wesselmanlaan 25	Helmond	5707 HA
42	Spaarne Gasthuis	Spaarnepoort 421	Hoofddorp	2134 TM
43	Westfries Gasthuis	Fr Maelsonstraat 3	Hoorn	1624 NP
44	Medisch Centrum Leeuwarden	H Dunantweg 2	Leeuwarden	8934 AD
45	Leids Universitair Medisch Centrum	Albinusdreef 2	Leiden	2333 ZA
46	Alrijne Ziekenhuis	Simon Smitweg 1	Leiderdorp	2353 GA
47	Maastricht UMC+	P Debijelaan 25	Maastricht	6229 HX
48	St. Antonius Ziekenhuis	Koekoekslaan 1	Nieuwegein	3435 CM
49	Canisius-Wilhelmina Ziekenhuis	Weg door Jonkerbos 100	Nijmegen	6532 SZ
50	Radboudumc	G Grooteplein Zuid 10	Nijmegen	6525 GA
51	Waterlandziekenhuis	Waterlandlaan 250	Purmerend	1441 RN
52	Laurentius Ziekenhuis	Mgr Driessenstraat 6	Roermond	6043 CV
53	Erasmus Medisch Centrum	Gravendijkwal 230	Rotterdam	3015 CE
54	Franciscus Gasthuis & Vlietland	Kleiweg 500	Rotterdam	3045 PM
55	Ikazia Ziekenhuis	Montessoriweg 1	Rotterdam	3083 AN
56	Maasstad Ziekenhuis	Maasstadweg 21	Rotterdam	3079 DZ
57	Franciscus Gasthuis & Vlietland	Vlietlandplein 2	Schiedam	3118 JH
58	Stichting Reinier Haga Groep	Leyweg 275	Den Haag	2545 CH
59	MCH-Bronovo	Lijnbaan 32	Den Haag	2512 VA
60	MCH-Bronovo	Bronovolaan 5	Den Haag	2597 AX
61	Jeroen Bosch Ziekenhuis	Henri Dunantstraat 1	Den Bosch	5223 GZ
62	Antonius Ziekenhuis	Bolswarderbaan 1	Sneek	8601 ZK
63	Zorgsaam	Wielingenlaan 2	Terneuzen	4535 PA
64	Ziekenhuis Rivierenland	Pres Kennedylaan 1	Tiel	4002 WP
65	Elisabeth-TweeSteden Ziekenhuis	Hilvarenbeekseweg 651	Tilburg	5022 GC
66	Bernhoven	Nistelrodeseweg 661	Uden	5406 PT
67	St. Antonius Ziekenhuis	Soestwetering 1	Utrecht	3543 AZ

68	Diakonessenhuis	Bosboomstraat 1	Utrecht	3582 KE
69	Universitair Medisch Centrum Utrecht	Lundlaan 6	Utrecht	3584 EA
70	Máxima Medisch Centrum	de Run 4600	Veldhoven	5504 DB
71	VieCuri Medisch Centrum	Tegelseweg 210	Venlo	5912 BL
72	St. Jans Gasthuis	Vogelsbleek 5	Weert	6001 BE
73	Ommelander Ziekenhuis Groningen	Gassingel 18	Winschoten	9671 CX
74	Streekziekenhuis Koningin Beatrix	Beatrixpark 1	Winterswijk	7101 BN
75	Zaans Medisch Centrum	Koningin Julianaplein 58	Zaandam	1502 DV
76	LangeLand Ziekenhuis	Toneellaan 1	Zoetermeer	2725 NA
77	Gelre Ziekenhuizen	Den Elterweg 77	Zutphen	7207 AE
78	Isala	Dokter van Heesweg 2	Zwolle	8025 AB

Appendix G R scripts used to gather and prepare data

This appendix contains all scripts that have been used in R. The scripts are presented in the order of usage. All scripts are written in a way that it should be rather easy to reproduce the calculations. Moreover, the descriptive lines (#) ensure the scripts are self-explanatory.

Script 6 Preparation of the departure locations - R

```
#Charlotte Giesbers (Delft University of Technology)
#February 28, 2018
#version 1.5
#****************************************************************************************************

#The objective of this programme is to prepare a freely available (from
#http://www.sqlblog.nl/postcodetabel-nederland-sql-script/) table that contains all address
#information in the Netherlands for using as input for the distance matrix by Google API
#****************************************************************************************************

#Required packages
#install.packages("tidyverse")  #only run once
library("tidyverse")

#open required zipcode file
Path <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
PostcodeTabel <- read.csv2(file.path(Path, "Postcodetabel.csv"), stringsAsFactors = FALSE)

#The table now looks as follows
#str(PostcodeTabel):
#'data.frame':  471781 obs. of  13 variables:
#$ PostcodeID     : int  14079 22504 33739 41151 56092 56516 60784 62170 73381 73910 ...
#$ PostCodePK     : chr  "1000EG_0" "1000AG_0" "1000CG_0" "1000AD_0" ...
#$ PostCode       : chr  "1000EG" "1000AG" "1000CG" "1000AD" ...
#$ PostcodeNummers: int  1000 1000 1000 1000 1000 1000 1000 1000 1000 1000 ...
#$ PostcodeLetters: chr  "EG" "AG" "CG" "AD" ...
#$ Straat         : chr  "Postbus" "Postbus" "Postbus" "Postbus" ...
#$ MinNummer      : int  0 0 0 0 0 0 0 0 0 0 ...
#$ MaxNummer      : int  10000 10000 10000 10000 10000 10000 10000 10000 10000 10000 ...
#$ Plaats         : chr  "Amsterdam" "Amsterdam" "Amsterdam" "Amsterdam" ...
#$ Gemeente       : chr  "Amsterdam" "Amsterdam" "Amsterdam" "Amsterdam" ...
#$ Provincie      : chr  "Noord-Holland" "Noord-Holland" "Noord-Holland" "Noord-Holland" ...
#$ Latitude       : num  52.4 52.4 52.4 52.4 52.4 ...
#$ Longitude      : num  4.91 4.91 4.91 4.91 4.91 ...

#Delete all "Postbus" rows
ZipCodeTable <- PostcodeTabel[!grepl("Postbus", PostcodeTabel$Straat), ]

#remove colums that are not needed
#remove numbering in original table)
#remove full zip and streetnames and numbers
#remove municipality and province
#remove copies of latitudes and longitudes
ZipCodeTable <- ZipCodeTable[, -c(1:3,5:8,10:11)]

#Translate column names
colnames(ZipCodeTable)[c(1:2)] <- c("Zip4d", "City")

#Create new column containing "The Netherlands" separated by a "+" for the Google API
ZipCodeTable <- cbind(ZipCodeTable, "The+Netherlands", stringsAsFactors = FALSE)
colnames(ZipCodeTable)[5] <- "Country" #Change column name to country

#Calculate the average latitude based on zipcode
MeanLat <- ZipCodeTable %>%
  group_by(Zip4d) %>%
  summarise(average = mean(Latitude))

#Calculate the average longitude based on zipcode
MeanLong <- ZipCodeTable %>%
  group_by(Zip4d) %>%
  summarise(average = mean(Longitude))

#Delete all duplicate rows based on zipcodes, to reduce data set to n = 4059, or all 4 digit zipcodes
ZipCodeTable <- ZipCodeTable[!duplicated(ZipCodeTable$Zip4d), ]
```

```
#Add these new average variables to the main table
#One by one to avoid copying "by" column, plus rename
ZipCodeTable <- merge(ZipCodeTable, MeanLat)
colnames(ZipCodeTable)[6] <- "MeanLat"
ZipCodeTable <- merge(ZipCodeTable, MeanLong)
colnames(ZipCodeTable)[7] <- "MeanLong"

#Create usable string variable for geolocation (GC) to be used in Google API distance matrix
#Separator needs to be a "+" for the Google API
OrLatLong <- with(ZipCodeTable, paste(MeanLat, MeanLong, sep = "+"))
ZipCodeTable <- cbind(ZipCodeTable, OrLatLong, stringsAsFactors = FALSE)

#Create usable string variable for zipcodes to be used in Google API distance matrix
#Separator needs to be a "+" for the Google API
OrZIP <- with(ZipCodeTable, paste(Zip4d, City, Country, sep = "+"))

#Google API cannot handle blank spaces as input, so all these need to be replaced by a "+"
OrZIP <- str_replace_all(OrZIP, " ", "+")

#Add column to main table
ZipCodeTable <- cbind(ZipCodeTable, OrZIP, stringsAsFactors = FALSE)

View(head(ZipCodeTable)) #do not run

#save file in a new csv file in the same folder
#All updated/changed files get a "2" after their original file name
OutputPath <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
write.csv2(ZipCodeTable, file.path(OutputPath, "Postcodetabel2.csv"))
```

Script 7 Preparation of the destination data - R

```
#Charlotte Giesbers (Delft University of Technology)
#February 28, 2019
#version 1.2
#*****************************************************************************************************

#The objective of this script is to prepare the destination data. In other ways, create a usable
#file for the 78 acute obstetrics locations in the Netherlands. This is done based on the list of
#acute obstetrics locations and addresses, provided by Giesbers (RIVM) This list has manually been
#updated in #December 2018 and checked for correctness using the addresses found on the websites of
#the hospitals.
#This file can be used by anyone that wants to use the "geocode" function. However, one should
#note a personal google API key is required.
#*****************************************************************************************************


#Required packages
#install.packages("stringr")  #helps in preparing the strings
#install.packages("ggmap")     #delivers geolocations using Google API
library("stringr")
library("ggmap")
#*****************************************************************************************************

#Open the file that contains all addresses
Path <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
HospitalTable <- read.csv2(file.path(Path, "AdressenlijstAV.csv"), stringsAsFactors = FALSE)

str(HospitalTable)
#'data.frame':  78 obs. of  8 variables:
#$ nr      : int  1 2 3 4 5 6 7 8 9 10 ...
#$ algzkhnr: int  103701 109002 101901 103604 100801 106304 106301 107901 100101 102103 ...
#$ algorgnm: chr  "Noordwest Ziekenhuisgroep" "Ziekenhuisgroep Twente" "Flevoziekenhuis" ...
#$ algzkhnm: chr  "Noordwest Ziekenhuisgroep locatie Alkmaar" "Ziekenhuisgroep Twente Almelo" ...
#$ adres   : chr  "Wilhelminalaan 12" "Zilvermeeuw 1" "Hospitaalweg 1" "Maatweg 3" ...
#$ alglocpl: chr  "Alkmaar" "Almelo" "Almere" "Amersfoort" ...
#$ postcode: chr  "1815 JD" "7609 PP" "1315 RA" "3813 TZ" ...
#$ X       : logi  NA NA NA NA NA NA ...

#delete the last column named "X"
DestTable <- HospitalTable[, -8]
```

```
#delete the first column that contains numbers, and the names and numbers
DestTable <- DestTable[, -c(1:3)]

#Translate column names
colnames(DestTable)[c(1:4)] <- c("HospitalName", "Address", "City", "Zipcode")

#Add column containing "The Netherlands"
DestTable <- cbind(DestTable, "The Netherlands", stringsAsFactors = FALSE)
colnames(DestTable)[5] <- "Country" #Change column name to country

#The input for the distance time matrix of Google API requires Full Address strings with "+" as a
#separator
#So first, all columns (Address, Zipcode, Place, Country) wil be merged into one column
DestTable <- cbind(DestTable, with(DestTable, paste(Address, Zipcode, City, Country)),
                   stringsAsFactors = FALSE)
colnames(DestTable)[6] <- "DestFullAddress"

#As said, it is needed to replace all " " that are in the FullAddress column by "+"
DestTable <- cbind(DestTable, str_replace_all(DestTable$DestFullAddress, " ", "+"),
                   stringsAsFactors = FALSE)
colnames(DestTable)[7] <- "DestFullAddressPlus"

#*****************************************************************************************************
#Finally, later on, it may be useful to have geolocations of the addresses. Using geocode by
#"ggmap", the full #addresses will be converted into latlongs, separated by a "+" again.

#set API key for Google API
key <- "xxx"
register_google(key)

#geocode simply requires the full addresses as input
#HospitalGC <- geocode(DestTable$DestFullAddress)       #ONLY RUN ONCE

#add results to table
DestTable <- cbind(DestTable, HospitalGC, stringsAsFactors = FALSE)
colnames(DestTable)[c(8,9)] <- c("DestLong", "DestLat")

#add a merged column with the LatLong, separated by a "+"
DestTable <- cbind(DestTable, with(DestTable, paste(DestLat, DestLong, sep = "+")),
                   stringsAsFactors = FALSE)
colnames(DestTable)[10] <- "DestLatLong"

View(head(DestTable))

#save file in a new csv file in the same folder
write.csv2(DestTable, file.path(Path, "AdressenlijstAV2.csv"))
```

Script 8 Acquisition of travel distances and travel times - R

```
#Charlotte Giesbers (Delft University of Technology)
#March 4, 2019
#Version 1.6
#*****************************************************************************************************

#The objective of this script is to obtain a time and distance matrix using all four digit zipcodes
#in the Netherlands as origins, and all 78 acute obstetrics locations in the Netherlands as the
#destinations. This is done using the package "gmapsdistance" as developed by Rodrigo Azuero and
#David Zarruk.
#The required input is a file that contains origins and a file that contains destinations
#This file can be used by anyone that wants to use the "gmapsdistance" function. However, one
#should note a personal google API key is required.
#*****************************************************************************************************

#Install required packages
#install.packages("gmapsdistance")  #uses Google API to calculate distance time matrix

#Open file containing Zipcodes for the origins
Path <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
OrTable <- read.csv2(file.path(Path, "Postcodetabel2.csv"), stringsAsFactors = FALSE)
DestTable <- read.csv2(file.path(Path, "AdressenlijstAV2.csv"), stringsAsFactors = FALSE)

#Getfirst 100 from Origins table
OriginAll <- OrTable$OrLatLong
```

```
#Save list of all four digit zips and the average longlats
Zip_LL <- data.frame(OrTable[, c(2,9)], stringsAsFactors = FALSE)
write.csv2(Zip_LL, file.path(Path, "Zip_LL.csv"))

library("gmapsdistance")

#Set destination using the address with a "+" as a separator
FullAddresses <- DestTable$DestFullAddressPlus

#Insert API key as a string value
APIkey = "xxx"

#ONLY RUN ONCE:
#TTDistMatrix <- gmapsdistance(origin = OriginAll,
#                              destination = First20FullAdd,
#                              combinations = "all",
#                              mode = "driving",
#                              key = APIkey,
#                              dep_date = "2020-06-16",
#                              dep_time = "11:00:00")

#Save files
write.csv2(TTDistMatrix[["Time"]], file.path(Path, "Times.csv"))
write.csv2(TTDistMatrix[["Distance"]], file.path(Path, "Distance.csv"))
```

Script 9 Preparation of travel time and travel distance matrices - R

```
#Charlotte Giesbers (Delft University of Technology)
#March 13, 2019
#Version 1.2
#*************************************************************************************************

#The objective of this file is to inspect, check and update the values that have been obtained
#by the Gmapsdistance.R script. The distance and time matrices are both prepared for further usage.
#*************************************************************************************************

#Using the CBS 1 January 2019 update, the zipcodes have been checked. This lead to manual deletion
#of zipcode 9640, 7940 and 7342 later on.
#*************************************************************************************************

#required packages
#NA

#import all distance matrices
Path <- "C:/Users/charl/Documents/Delft University of Technology/R/Data"
DistanceMatrix <- read.csv2(file.path(Path, "Distances.csv"), stringsAsFactors = FALSE)

#delete "x"
DistanceMatrix <- DistanceMatrix[, -1]

#Now set the 4 digit Zipcodes as rownames
#First import the list of Zipcodes and their longlats
Zip_LL <- read.csv2(file.path(Path, "Zip_LL.csv"), stringsAsFactors = FALSE)

#Set names
row.names(DistanceMatrix) <- Zip_LL$Zip4d

#Delete column containing coordinates
DistanceMatrix <- DistanceMatrix[, -1]

#save this file
write.csv2(DistanceMatrix, file.path(Path, "DistanceMatrixOriginal.csv"))
#*************************************************************************************************
#Now we have a full distance matrix (of which the code can directly be copied for the timematrix,
#simply by replacing "Distance" and "Dist" by "Time"). It is time to see if there are any missing
#values and replace these with the correct values.

print(rownames(DistanceMatrix[!complete.cases(DistanceMatrix), ]))
#returns 8899 and 9166. These are both on an island: on Vlieland and Schiermonnikoog, respectively.

#First, Vlieland. No cars are allowed on Vlieland, and the boat trip to the island is about 34.5 km
#or 34500 meters. The average distance from zipcode 8899 on Vlieland to the port is about 1.8 km,
```

```r
#which brings the total distance traveled before getting to the arrival port of Harlingen (zipcode
#8861) to 36300 meters.
DistanceMatrix["8899", ] <- DistanceMatrix["8861", ] + 36300

#Second, Schiermonnikoog. No cars are allowed on Schiermonnikoog, and the boat trip to the island
#is about 10,8 km or 10800 meters. The average distance from zipcode 9166 on Vlieland to the port
#is about 2.8 km, which brings the total distance traveled before getting to the arrival port of
#Lauwersoog (zipcode 9976) to 13600 meters.
DistanceMatrix["9166", ] <- DistanceMatrix["9976", ] + 13600

print(rownames(DistanceMatrix[!complete.cases(DistanceMatrix), ]))
#Now returns nothing. This means the matrix can be saved.

write.csv2(DistanceMatrix, file.path(Path, "DistanceMatrix2.csv"))
#**************************************************************************************************

#Now, on to the time matrix. This program is practically just copy-pasted, except for the last
#couple of lines that update particular values.
#import all time matrices
TimeMatrix <- read.csv2(file.path(Path, "Times.csv"), stringsAsFactors = FALSE)

#delete "x"
TimeMatrix <- TimeMatrix[, -1]

#Now set the 4 digit Zipcodes as rownames
#First import the list of Zipcodes and their longlats
Zip_LL <- read.csv2(file.path(Path, "Zip_LL.csv"), stringsAsFactors = FALSE)

#Set names
row.names(TimeMatrix) <- Zip_LL$Zip4d

#Delete column containing coordinates
TimeMatrix <- TimeMatrix[, -1]

#save this file
write.csv2(TimeMatrix, file.path(Path, "TimeMatrixOriginal.csv"))

#**************************************************************************************************
#Now we have a full travel time matrix. It is time to see if there are any missing values and
#replace these with the correct values.

print(rownames(TimeMatrix[!complete.cases(TimeMatrix), ]))
#returns 8899 and 9166. These are both on an island: on Vlieland and Schiermonnikoog, respectively.

#First, Vlieland. No cars are allowed on Vlieland, the fastboat trip to the island takes 45 minutes
#or 5700 seconds. We assume it takes, on average, 30 minutes or 1800 seconds to get to the Vlieland
#port. The most efficient time and departure schedule are assumed, which brings time to 4500
#seconds before getting to the arrival port: Harlingen (zipcode 8861). The travel time to this port
#and travel time from port to hospital will be summed together.
TimeMatrix["8899", ] <- TimeMatrix["8861", ] + 4500

#Second, Schiermonnikoog. No cars are allowed on Schiermonnikoog, and the fastboat trip takes 20
#minutes or 1200 seconds. We assume it takes, on average, 45 minutes or 2700 seconds to get to the
#Schiermonnikoog port. The most efficient time and departure schedule are assumed, which brings
#time to 3900 seconds before getting to the arrival port: Lauwersoog (zipcode 9976). The travel
#time to this port and travel time from port to hospital will be summed together.
TimeMatrix["9166", ] <- TimeMatrix["9976", ] + 3900

print(rownames(TimeMatrix[!complete.cases(TimeMatrix), ]))
#Now returns nothing. This means the matrix can be saved.

write.csv2(TimeMatrix, file.path(Path, "TimeMatrix2.csv"))
```

Appendix H Substitutability scripts

This appendix contains a script that can be used by any researcher seeking substitutability values for any situation. Script 10 requires a distance and a time matrix and should be self-explanatory.

Script 10 Substitutability value script, reproducible example - R

```r
#Charlotte Giesbers (Delft University of Technology)
#April 27, 2019
#Version 1.2
#*****************************************************************************************************

#This file is used to set up a programme to calculate substitutability values, as described by Van
#Wee, Van Cranenburgh and Maat (2019).
#The minimum required input includes two origin-destination matrices, one that contains travel
#times and one with travel costs (or distances). The user can define parameter values (Beta_Time
#and Beta_Cost).

#In the example, a distance matrix is used as input, and travel cost per kilometre
#are used to retrieve the cost matrix. Furthermore, the travel times are in seconds and travel
#distances in meters, as this is the output given by Google Distance Matrix API.
#*****************************************************************************************************

#required packages
#NA

#import matrices, make sure the right path is defined and the file names are spelled correctly
#Note: the matrices should be of the same size and have the same origins and destinations
#Note: the matrices contain a column with origin names and the first row contains the destinations
Path <- "C:/Users/charl/Downloads"
TimeMatrix <- read.csv2(file.path(Path, "TimeMatrix.csv"), stringsAsFactors = FALSE)
DistanceMatrix <- read.csv2(file.path(Path, "DistanceMatrix.csv"), stringsAsFactors = FALSE)
OriginNames <- read.csv2(file.path(Path, "OriginNames.csv"), stringsAsFactors = FALSE)
#*****************************************************************************************************


#Set row names based on the OriginNames file. Make sure the header of the column that contains the
#origins is named "Origins" or set below
row.names(DistanceMatrix) <- OriginNames$Origins
row.names(TimeMatrix) <- OriginNames$Origins

#Delete the column that contained the origin name as these are now in the row names
DistanceMatrix <- DistanceMatrix[, -1]
TimeMatrix <- TimeMatrix[, -1]

#set parameter values. The car costs are only required if the input is a distance matrix as in the
#example.
Beta_Time <- -0.2 #util/minute
Beta_Cost <- -0.5 #util/euro
CarCostspkm <- 0.2 #cost per kilometre

#Recalculate matrices. For this example, this is required. Make sure you have the same inputformat
#Times should be in minutes
TimeMatrixMins <- TimeMatrix/60

#Distances should be in kilometres
DistanceMatrixKm <- DistanceMatrix/1000

#calculate cost matrix based on distance matrix
CostMatrix <- DistanceMatrixKm * CarCostspkm

#*****************************************************************************************************
#Calculating utility per o-d combination using BetaTime*time+BetaCost*cost
UtilityMatrix <- (TimeMatrixMins*Beta_Time + CostMatrix*Beta_Cost)

#Create Matrix with e^utility (needed to calculate choice probabilities)
ExpSum <- rowSums(exp(UtilityMatrix))

#Calculate choice probabilities per row and check outcomes
ProbMatrix <- exp(UtilityMatrix)/ExpSum
View(rowSums(ProbMatrix)) #should all be equal to 1!
```

```r

#Calculate the expected utility, without the preferred alternative
LSy_i <- log(ExpSum-exp(UtilityMatrix))

#Calculate Logsums
LogSum <- log(ExpSum)

#Calculate the substitutability values
Subst <- 1/(LogSum-(rowSums(ProbMatrix*LSy_i)))

#Normalise the substitutability values
Norm_Subst <- 1-(1/(1+Subst))

#create usable dataframe
Substitutability <- cbind(Subst, Norm_Subst)

#Save the file in the same folder as the input
write.csv2(Substitutability, file.path(Path, "Substitutability.csv"))
```

Finally, Script 11 is the script that has been used for this particular study. It contains a few data preparation steps as well, for example for the costs and travel times for the islands in the far north of the Netherlands.

Script 11 Script used for substitutability and data preparation - R

```r
#Charlotte Giesbers (Delft University of Technology)
#March 30, 2019
#Version 1.2
#*****************************************************************************************

#This file is used to set up a programme to calculate substitutability values, as described by Van
#Wee, Van Cranenburgh and Maat (2018). The input that #is required includes two origin-destination
#matrices, one that contains travel distance and one with travel times. Also two parameters are
#needed: a travel cost and travel time beta value. For this test file, an assumption about these
#values is made.
#*****************************************************************************************
#Using the CBS 1 January 2019 update, the zipcodes have been  .
#*****************************************************************************************

#required packages
#NA

#import matrices
Path <- "C:/Users/charl/Documents/R/Data"
TimeMatrix  <- read.csv2(file.path(Path, "TimeMatrix.csv"), stringsAsFactors = FALSE)
DistanceMatrix  <- read.csv2(file.path(Path, "DistanceMatrix.csv"), stringsAsFactors = FALSE)
Zip_LL  <- read.csv2(file.path(Path, "Zip_LL.csv"), stringsAsFactors = FALSE)
#*****************************************************************************************

#Set names
row.names(DistanceMatrix) <- Zip_LL$Zip4d
row.names(TimeMatrix) <- Zip_LL$Zip4d

#Delete column containing zip
DistanceMatrix <- DistanceMatrix[, -1]
TimeMatrix <- TimeMatrix[, -1]

#set parameters
Beta_Time <- -0.0924 #util/minute
Beta_Cost <- -0.0683 #util/euro
CarCostspkm <- 0.19

#Recalculate matrices
#Times should be in minutes
Min_TimeMatrix <- TimeMatrix/60

#Distances should be in kilometers
Km_DistanceMatrix <- DistanceMatrix/1000
#*****************************************************************************************

```

```
#However, distances need a little more preparation re the islands in the North of the Netherlands
#So for the islands on which cars are allowed (Texel, Terschelling and Ameland), the CarCosts equal
#("Total trip km" - "Boat km") * CarCostspkm and total costs equal CarCosts + BoatCosts.
#For the islands on which cars are not allowed (Schiermonnikoog and Ameland), CarCosts equal
#("Total trip km" - "boat km" - "on island km") * CarCostspkm and total costs equal CarCosts +
#BoatCosts.
#Furthermore, BoatCosts are the costs in eurosfor a one-way trip without a car. On all fast
#services, no #cars can be transported. As the fastest trip is taken into account, an efficien
#planning is and pick up by car at the arrival port are assumed.

#Define zipcodes per island
Texel <- c("1791", "1792", "1793", "1794", "1795", "1796", "1797")
Vlieland <- "8899"
Terschelling <- c("8881", "8882", "8883", "8884", "8885", "8891", "8892", "8893", "8894",
                  "8895", "8896", "8897")
Ameland <- c("9161", "9162", "9163", "9164")
Schiermonnikoog <- "9166"
Islands <- c(Texel, Vlieland, Terschelling, Ameland, Schiermonnikoog)

#Boatcosts
BoatCosts <- function(x){
  if(x %in% Texel){
    BoatCosts = 1.25
  } else if(x %in% Vlieland){
    BoatCosts = 22.82
  } else if(x %in% Terschelling){
    BoatCosts = 22.82
  } else if(x %in% Ameland){
    BoatCosts = 21.35
  } else if(x %in% Schiermonnikoog){
    BoatCosts = 21.35
  } else {BoatCosts = 0}
}

#Island Kilometers
IslandKm <- function(x){
  if(x %in% Texel){
    IslandKm = 4.8
  } else if(x %in% Vlieland){
    IslandKm = 36.3
  } else if(x %in% Terschelling){
    IslandKm = 38.3
  } else if(x %in% Ameland){
    IslandKm = 11.6
  } else if(x %in% Schiermonnikoog){
    IslandKm = 13.6
  } else {IslandKm = 0}
}

#calculate Cost Matrix
CostMatrix <- Km_DistanceMatrix * CarCostspkm

CostMatrix[Islands, ] <- ((Km_DistanceMatrix[Islands, ] - IslandKm(Islands))
                          * CarCostspkm
                          + BoatCosts(Islands))

#Calculating utility per o-d combination using BetaTime*time+BetaCost*costs
UtilityMatrix <- (Min_TimeMatrix *Beta_Time + CostMatrix *Beta_Cost)

#Create Matrix  with e^utility (needed to calculate choice probabilities)
ExpSum <- rowSums(exp(UtilityMatrix))
ProbMatrix <- exp(UtilityMatrix)/ExpSum
#View(rowSums(ProbMatrix)) #should all be equal to 1

#Calculate LogSum without preferred alternative
LSy_i <- log(ExpSum-exp(UtilityMatrix))

#Calculate total LogSum
LogSum <- log(ExpSum)

#Calculate substitutability values
Subst <- 1/(LogSum-(rowSums(ProbMatrix *LSy_i)))
```

```
#Calculate normalised substitutability
Norm_Subst <- 1-(1/(1+Subst))

MinimumTime <- apply(Min_TimeMatrix, 1, FUN=min)

#create usable dataframe
Substitutability <- cbind(LogSum, Subst, Norm_Subst, MinimumTime)

#Save data file
write.csv2(Substitutability, file.path(Path, "Substitutability.csv"))
```

Appendix I Scientific article

Empirical research on the distribution of hospitals in the Netherlands

Substitutability of hospital locations: the case of obstetrics care

Charlotte Giesbers
Complex Systems Engineering and Management, Faculty of Technology, Policy & Management, Delft University of Technology, The Netherlands.

Abstract The acute obstetrics (AO) sector in the Netherlands faces two challenges. The increasing difficulty to find personnel and the closing down of several locations have put a major pressure on the existing AO locations. This has led to questions about the quality of the spatial distribution. The measures currently in place are based the travel time to the closest hospital. However, the recent developments have forced AO locations to say 'no' when asked to take care of a woman in labour. In other words, the unavailability of beds in the nearest hospital. The current accessibility measures cannot capture this and therefore the concept of substitutability is introduced. The mathematical model for substitutability offers a possibility to assess the effect of elimination of the preferred option. The input parameters for the substitutability calculations have been derived from a stated choice experiment among 151 female residents of the Netherlands. The cost and time parameters were estimated using a multi nominal logit model. A comparison between minimum travel time, LogSum accessibility values and normalised substitutability values guided the assessment of the spatial distribution. This comparison provided insights in new critical areas of the network. The study serves as an exploration of substitutability and it has proved it to be a promising concept for future research.

Key words Acute obstetrics; hospital decision making; stated choice experiment; substitutability.

1. Introduction

The high population density of the Netherlands makes spatial distribution of key services such as hospital care a relatively manageable problem. The performance of the spatial distribution of hospitals is assessed using accessibility measurements such as the travel time to the closest hospital. Furthermore, there are legal agreements in place that state a hospital cannot be closed down if it is a 'sensitive' hospital. A hospital is marked as sensitive if "if, according to the theoretic model, the number of residents that may take more than 45 minutes to be brought to an increases when this hospital closes." (Kommer, Gijsen, De Bruin-Kooistra, & Deuning, 2017, p. 5).

Recent developments in the hospital care and in particular the acute obstetrics (AO) sector have put an increasing pressure on the system. First, it is increasingly difficult to find personnel and the number of hard-to-fill vacancies has seen a new high in 2018 (BDO, 2018; Leensen, Poulssen, & Weststrate, 2018). This has forced hospitals to sometimes temporarily close down parts of their total bed capacity (Weeda, 2018a, 2018b).

Furthermore, the closing down of some hospitals, bringing down the number of AO locations from 84 in 2015 to 78 by the end of December 2018. This has put pressure on the remaining locations as these have to take over the treatments. Even if the hospital has beds available, there is no personnel to take care of new patients. Consequently, 80% of pregnant women does not deliver in the preferred hospital and about two thirds of the midwives has to call multiple hospitals before finding an available bed (KNOV, 2018; Wassenaar, 2017).

The performance measures in place and the theoretical models underlying these are all based on the assumption that a patient visits the nearest hospital. More importantly, it assumed the patients concerned can actually receive the required aid at the nearest hospital. However, as a consequence of the aforementioned developments, this nearby hospital may not be an option for a patient. This effect cannot be captured by the accessibility measures currently in place. To fill this gap, the concept of substitutability as introduced by Van Wee and Van Cranenburgh (2017) is proposed.

Substitutability can capture "the extent to which the preferred travel alternative can be substituted by other initially less preferred alternatives." (Van Wee, Van Cranenburgh, & Maat, 2018, p. 2). In other words, the mathematical model for substitutability offers a possibility to assess the effect of the unavailability of the nearest hospital. This could provide interesting insights for the spatial distribution of the AO sector in the Netherlands. To the best of my knowledge, substitutability has not yet been thoroughly researched. Therefore, this paper serves as an explorative study.

The remainder of this paper is structured as follows. Section 2 summarizes the current situation in the AO sector in the Netherlands and the types of measurements often used to assess accessibility. The section also presents a list of factors that are expected to be important to AO location choice for females in the Netherlands. In Section 3, the methodology is briefly discussed. The results are presented in Section 4 while Section 5 contains a discussion of these results. In the final section, Section 6, the conclusions and some recommendations for future research are presented.

2. Literature review

The public hospital sector in the Netherlands can be divided into four different categories. 100 general hospitals, 8 academic hospitals, 7 children's hospitals and 131 outlying polyclinic facilities. 78 of these are officially recognised as hospitals that provide AO care (RIVM, 2018b). Theoretically speaking, 99.7% of women in the fertile age (15-50 years) can reach an AO location within 30 minutes by car (CBS, 2019a; RIVM, 2018a). The spatial distribution of the locations, the sensitive hospitals and the travel time to the closest hospital are visualised in Figure 1. The sensitivity of hospitals is based on June 2018. Critical areas are found in the coastal areas of Zeeland, Friesland and Groningen, on the islands and, because of recent bankruptcy of the Lelystad hospital, in the northern part of Flevoland.

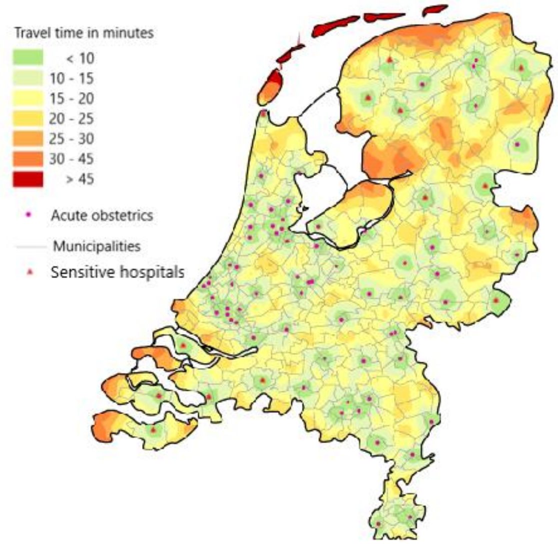


Figure 1 Travel time to closest AO location, update December 2018 (adapted from RIVM)

There are several methods to assess geographical accessibility. For the spatial distribution of hospitals, some methods are applied often. Several researchers have given comprehensive reviews of these assessment methods (e.g. Bhat et al., 2000; Hanson & Schwab, 1987; Joseph & Phillips, 1984; Love & Lindquist, 1995; Martin & Williams, 1992). A recapitulatory overview of six of these measures is given in Table 1. CBS applies the choice-set method by keeping track of the number of hospitals within a certain reach on a provincial and municipal level (CBS, 2019d).

Table 1 Accessibility measures for the hospital sector (adapted from Love & Lindquist and Martin & Williams)

Measure	Description
Choice-set	Number of hospitals within a certain distance
Extended choice-set	Includes additional factors such as a distinction between rural and urban areas
Minimum distance	Distance to closest hospital
Mean distance	Average of the distances to each of the hospitals weighed by the probability of usage
Hansen	Includes attractiveness of hospital, reflecting the propensity to travel for hospitals
LogSum	Hansen including a natural logarithm

For AO distribution specifically, there are two measures in place, both related to the minimum distance measure. One tracks ambulance trips while the other is focused on accessibility by car (Kommer et al., 2017). The focus of this research is on driving times by car. Before being able to calculate the substitutability values, the next step is identification of travel time and travel cost parameters.

In order to make a correct assessment of the cost and time parameters for females in AO decision making, a stated choice (SC) experiment has been conducted. The experiment is kept simple as the main objective is to identify a significant Value of Travel Time (VoTT). Other factors that have been included are based on existing literature. Quality of care, diagnosis (e.g. Basu & Cooper, 2005; Bronstein & Morrisey, 1991), size of hospital (e.g. Adams, Houchens, Wright, & Robbins, 1991; Tai, Porell, & Adams, 2004), satisfaction about a hospital (e.g. Liu, Bellamy, & McCormick, 2007; Tai et al., 2004), income (Liu et al., 2007) and travel time have been proved to be important factors in hospital decision making. Concludingly, it is important to consider these factors for the SC experiment. This and the rest of the methods will be elaborated on in the next section.

3. Methodology

The different steps of the study will be discussed in this chapter. After the literature review as presented in the previous section, a SC experiment is conducted. Based on the outcomes of this survey, the input parameters for substitutability are estimated. The substitutability calculation steps will briefly be discussed in this section as well.

Stated Choice experiment

The target group is females in the Netherlands. Distribution via Facebook and personal email communication reached 151 female respondents. By means of a pilot study and a Mean Bayesian D-efficient design, 7 choice sets were constructed in Ngene (ChoiceMetrics, 2018). One choice set included a strictly dominant alternative, to see whether or not the respondents correctly understood the task. The choice sets can be viewed in Table 2.

Table 2 Choice sets used in the final survey

CS	T1	C1	R1	A2	C2	R2
1	10	3.5	2	30	8.5	3
2	20	3.5	3	10	6	3
3	10	6	3	20	6	4
4	20	6	4	30	3.5	4
5	10	8.5	4	30	6	2
6	30	3.5	4	20	8.5	2
7	30	6	2	10	3.5	2

CS represents the number of the choice sets. The other columns include T for travel time (10, 20, 30 minutes), C for travel costs (3.5, 6, 8.5 euros) and R for recommendation (2, 3, 4 out of 5 stars).

The description page of the survey stated to assume every other factor (listed in the previous section) to be equal among the two alternatives. The survey also included personal questions on age, income, education, recent hospital visits, delivery, car ownership and four digit zip code. Based on the data obtained, the cost and time parameters have been estimated.

Substitutability

After estimation of the parameters, the substitutability values have been calculated. The mathematical model for substitutability as introduced by Van Wee et al. (2018), uses the following equations. The formulation is based on the well-known LogSum measure, as it is very closely related to accessibility as defined by Geurs and Van Wee (2004). So first, the value for LogSum LS_n is

$$LS_n = \ln\left(\sum_J e^{V_{jn}}\right) + C \qquad (1)$$

In which V_{jn} equals the observed utility of alternative i from available alternatives J for a certain decision maker n. C is an unknown constant that indicates that absolute utility cannot be measured. However, in decision-making, the main objective is comparing alternatives and identifying the best alternative in a certain choice set. Absolute values and therefore constant C are irrelevant in this case (Van Wee et al., 2019).

From an ex-ante perspective, the value for substitutability can now be calculated using the equation (2) in which P_i is incorporated in and represents the probability that alternative i is chosen by decisionmaker n. $LS_n^{Y=i}$ equals the value for LogSum without preferred alternative i. By weighing this with P_i, less preferred alternatives have a smaller impact on the value for substitutability S_n.

$$S_n = \frac{1}{LS_n - \sum_{i=1\ldots J} P_i * LS_n^{Y=i}} \tag{2}$$

To make substitutability values for different decisionmakers comparable to one another, Van Wee et al. (2018) proposed to normalize the value for S_n using equation (3).

$$\hat{S_n} = 1 - \frac{1}{1 + S_n} \tag{3}$$

The input for this model is the choice probability of different alternatives P_i, which in turn requires the utility values V_i for each alternative as shown in equation (4).

$$P_i = \frac{\exp(V_i)}{\sum_J \exp(V_j)} \tag{4}$$

The required β values to obtain utility values V are estimated using the SC data and the linear additive RUM-MNL model. These results are presented in the next section after discussing the sample characteristics.

4. Results

In total, 155 respondents started the survey, of which 151 females finished it. Two respondents were removed from the data set after analysis of the choice made in the seventh choice set, which included a dominant alternative. The sample characteristics, based on the personal questions about demographics, have been compared to the females population of the Netherlands (CBS, 2015, 2019c, 2019b; Perined, 2017).

In the sample, highly-educated, high-income females who live in (very) urban areas are overrepresented. Moreover, the peak in age groups in the sample is found in 20-25 and >50 years old. These overrepresentations can be attributed to the fact that the survey was distributed via the personal network.

The parameter estimation and model statistics based on the linear-additive RUM-MNL model are shown in Table 3. This model is estimated using PythonBiogeme (Bierlaire, 2018). McFadden's $\rho^2 = 0.328$ which indicates an acceptable level of explanatory power (McFadden, 1974). All estimated parameters are significant on a 99% confidence level.

Table 3 Estimation report RUM-MNL model

Name	Value	Std err	t-test	p-value
β_R	1.6	0.141	11.39	0.00
β_{TC}	-0.0683	0.0261	-2.62	0.01
β_{TT}	-0.0924	0.00935	-9.88	0.00
Number of estimated parameters:				3
Sample size:				894
LL null:				-619.674
Final LL:				-416.458
LRS:				406.431
Rho-square:				0.328

The utility effect of β_R is bigger than expected. Nevertheless, based on the outcomes of the RUM-MNL model, the following parameters are assumed to be suitable for the substitutability calculations.

$$\beta_{TC} = -0.0683$$
$$\beta_{TT} = -0.0924$$

Substitutability

Besides the cost and time parameters as presented above, travel time and travel cost matrices are needed. These are captured in two origin-destination matrices, in which the origins are represented by all 4059 habited four-digit zip codes in the Netherlands and the destinations are the 78 AO locations. Using R and a Google Distance Matrix API, the travel times and travel distances between these can be obtained (Azuero Melo, Rodriguez, & Zarruk, 2018; Kahle, Wickham, & Jackson, 2019). As it is assumed women travel to AO locations by car, the cost of usage are assumed to be €0.19 per kilometre (ANWB, 2018). This transforms the travel distance matrix into a travel cost matrix.

As it is difficult to judge the added value of substitutability relative to the other accessibility measures merely based on a table, Gephi is used to visualize the outcomes. Gephi allows the user to colour the geocoded locations according to a certain value. For reasons of interpretability, the bottom 25 values are left out of the visualization in Figure 2. The normalised substitutability map is shown in *Figure 3*. The minimum travel time evaluation is based on a map similar to that of RIVM (RIVM, 2018a, p. 7).

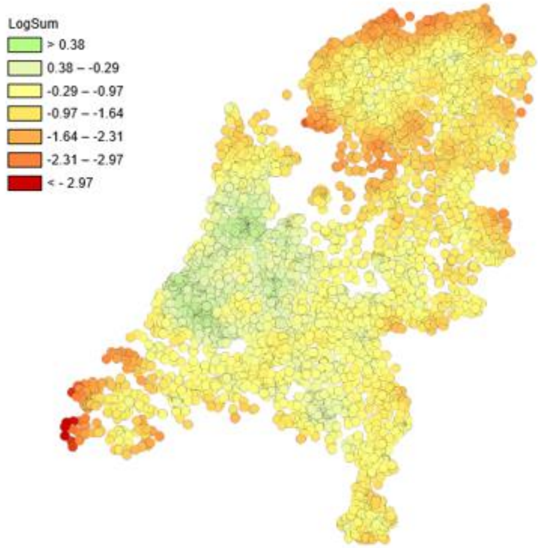


Figure 2 LogSum (after removal of the lowest 25)

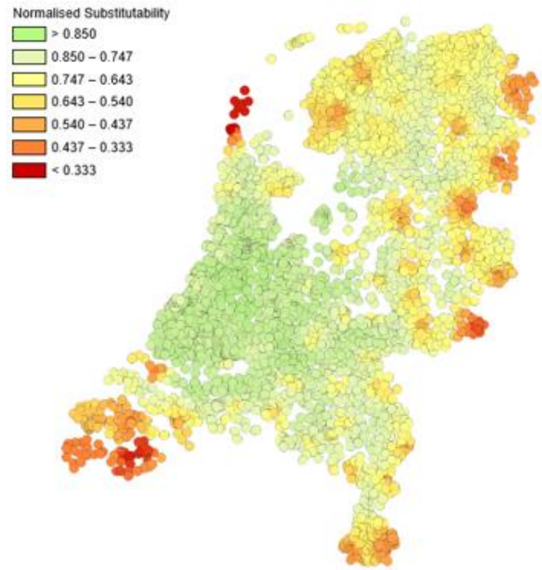


Figure 3 Normalised substitutability

Critical values for the measurements are found on the islands and in border areas. The map for substitutability clearly shows areas that have only one AO hospital in its vicinity, and indicates that in several areas (south in Limburg, most of Zeeland and many areas in the North of the country) the next option is usually not a suitable substitute.

Probably the most striking thing to the normalised substitutability map is found in the province of Flevoland. A lot of media reported on the problems in this area due to the long travel times to hospitals and the unavailability of beds and personnel. However, the fact that these areas score relatively good in normalised substitutability is in the nature of this measure: it compares the available options instead of rating them. It does not capture the long travel time to the four hospitals within an hour of Urk, it just states that whenever someone in this area is in need of AO care, there are 4 options that could easily be substituted by one another.

Based on the comparison of the calculated LogSum values, the travel time to the nearest hospital, the locations of the hospitals that are viewed as sensitive hospitals by RIVM and the new substitutability application as presented in this study, a suggestion for the spatial distribution of AO locations are presented in Section 6. First, the next section presents a discussion of the used methods and results.

5. Discussion

The discussion of this study refers to both the SC experiment as well as the substitutability calculations.

First, the SC experiment. One of the alternatives in the choice sets of the final survey (CS5) turned out to be dominated. This could have been prevented by testing the final survey on several respondents. Furthermore, the parameter for recommendation turned out to be more important than expected. This makes the validity of the estimated cost and time parameters vulnerable. The found value for travel time of €81.71 is a lot higher than the VoTTs found in existing literature. It is uncertain if the VoTT is valid and reliable.

Secondly, the model used for the estimation. The usage of a RUM-MNL model comes with several limitations. It does not allow to accommodate for the panel structure of the obtained data, as the 7 decisions made by one respondent are expected to be correlated. Another limitation is the fact that and MNL model does not allow for modelling heterogeneity within choice data. Furthermore, the estimation of a RUM-MNL model does not allow accounting for the fact that different people may use different decision rules (such as regret minimization, as explained by Chorus (2012)).

Moreover, the sample is not representative for the female population in the Netherlands.

For the substitutability calculations, the most important point of discussion is the fact that it is based on the parameters found by the model on the SC data. As the validity of the cost and time parameters is questionable, the substitutability results are prone to validity issues as well. Furthermore, the fact that the values for normalised substitutability are very sensitive to the values of the input parameters, puts pressure on the reliability of the results.

The discussion as presented in this section should be viewed as potential future research directions. As this study was merely a first explorative study, there is room for improvement on many subjects. Some recommendations are presented in the next section, after the conclusions have been presented.

6. Conclusions and recommendations

The objective of this study was to evaluate the spatial distribution of the AO locations in the Netherlands. This is done by comparing the well-known LogSum values and the minimum travel time values to the substitutability model as proposed by Van Wee et al. (2018). A stated choice experiment was conducted to find reliable parameters to base the substitutability calculations on.

As expected, a relatively high value of travel time of €81.71 per hour was found. As there is no research yet that defines value of travel time in emergency situations such as acute obstetrics care, there is no reason to reject the found parameters. It is assumed travel time is the most important factor for acute obstetrics location decision making for females in the Netherlands.

Based on the results of the comparison of the minimum travel times, the LogSum values and the substitutability values, it is suggested to mark the UMC in Maastricht and the Treant Scheper in Emmen as sensitive as well. This is visualised in Figure 4. These hospitals do not directly affect the number of women that cannot reach an AO location within the maximum ambulance trip time of 45 minutes. However, when taking into account the insights offered by the substitutability values, these hospitals show to be of critical value to the spatial distribution of AO locations. The unavailability of beds in one of these hospitals would have severe consequences for the well-being of pregnant females in these regions.

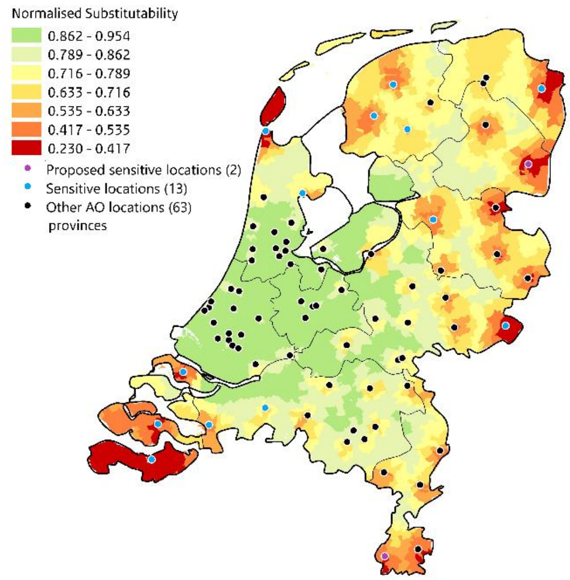


Figure 4 Proposed sensitive locations

Concludingly, the added value of substitutability can be found in that it offers new insights in the performance of a spatially distributed system. This research focused on the current distribution of AO locations. As it has been shown there are significant differences in the outcomes for the traditional accessibility measures and substitutability, it has the potential to be insightful in other situations as well.

Interesting future research directions are for instance the development of different model formulations, such as the unavailability of more than one preferred alternative. Another possibility is the application of substitutability to more complex hospital care sectors. One could think of applications in an area where the level of emergency is lower so that the value of travel time would be lower.

Related to this value of travel time, it is recommended to further research the cost and time parameters in health care for emergency situations. It is expected that the validity of the model as used in this study can be improved.

References

Adams, E. K., Houchens, R., Wright, G. E., & Robbins, J. (1991). Predicting Hospital Choice for Rural Medicare Beneficiaries: The Role of Severity of Illness. *Health Services Research, 26*(5), 583–612.

ANWB. (2018). Autokosten berekenen: bereken kosten per maand en per kilometer.

Retrieved December 12, 2018, from https://www.anwb.nl/auto/autokosten#/autokosten
Azuero Melo, R., Rodriguez, D., & Zarruk, D. (2018). Package "gmapsdistance." Retrieved from https://cran.r-project.org/web/packages/gmapsdistance/gmapsdistance.pdf
Basu, J., & Cooper, J. (2005). Out-of-Area Travel From Rural and Urban' Counties: A Study of Ambulatory Care Sensitive Hospitalizations for New York State Residents. *The Journal of Rural Health*, *16*(2), 129–138.
BDO. (2018). *Benchmark Ziekenhuizen 2018*.
Bhat, C., Kockelman, K., Qinglin, C., Handy, S., Mahmassani, H., & Weston, L. (2000). *Urban Accessibility Index: Literature Review*. Austin, TX.
Bierlaire, M. (2018). PythonBiogeme. Retrieved from https://biogeme.epfl.ch/
Bronstein, J. M., & Morrisey, M. A. (1991). Bypassing Rural Hospitals for Obstetrics Care. *Journal of Health Politics, Policy and Law*, *16*(1), 87–118.
CBS. (2015). StatLine - Personen in bezit van auto of motor; persoonskenmerken, 2010-2015. Retrieved April 16, 2019, from https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81844ned&D1=a&D2=a&D3=0,8-22,26-31&D4=l&VW=T
CBS. (2019a). Begrippen. Retrieved March 16, 2019, from https://www.cbs.nl/nl-nl/onze-diensten/methoden/begrippen
CBS. (2019b). *Doorsnee inkomen werkenden al 10 jaar vrijwel constant*. *Centraal Bureau voor de Statistiek*.
CBS. (2019c). StatLine - Bevolking; hoogstbehaald onderwijsniveau en onderwijsrichting. Retrieved April 16, 2019, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82816NED/table?ts=1555405678613
CBS. (2019d). StatLine - Nabijheid voorzieningen; afstand locatie, regionale cijfers. Retrieved April 18, 2019, from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80305ned/table?ts=1555599552788
ChoiceMetrics. (2018). *Ngene 1.2 User Manual and Reference Guide*. Sydney, Australia: ChoiceMetrics.
Chorus, C. G. (2012). Random Regret Minimization: An Overview of Model Properties and Empirical Evidence. *Transport Reviews*, *32*(1), 75–92. https://doi.org/10.1080/01441647.2011.609947
Geurs, K. T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography*, *12*(2), 127–140. https://doi.org/10.1016/J.JTRANGEO.2003.10.005
Hanson, S., & Schwab, M. (1987). Accessibility and Intraurban Travel. *Environment and Planning A: Economy and Space*, *19*(6), 735–748. https://doi.org/10.1068/a190735
Joseph, A. E., & Phillips, D. R. (1984). *Accessibility and utilization: geographical perspectives on health care delivery*. London: Harper & Row.
Kahle, D., Wickham, H., & Jackson, S. (2019). Package "ggmap." Retrieved from https://cran.r-project.org/web/packages/ggmap/ggmap.pdf
KNOV. (2018, November 16). Capaciteitsproblematiek neemt toe en leidt tot nijpende situaties. *Koninklijke Nederlandse Organisatie van Verloskundigen*.
Kommer, G. J., Gijsen, R., De Bruin-Kooistra, M., & Deuning, C. (2017). *Aanbod en bereikbaarheid van de spoedeisende ziekenhuiszorg in Nederland 2017: Analyse gevoelige ziekenhuizen 2017*. https://doi.org/10.21945/RIVM-2017-0108
Leensen, R., Poulssen, R., & Weststrate, E. (2018). *Barometer Nederlandse Gezondheidszorg 2018. Rendement zorg stijgt ten koste van personeel*.
Liu, J., Bellamy, G. R., & McCormick, M. (2007). Patient bypass behavior and critical access hospitals: Implications for patient retention. *Journal of Rural Health*, *23*(1), 17–24. https://doi.org/10.1111/j.1748-0361.2006.00063.x
Love, D., & Lindquist, P. (1995). The Geographical Accessibility of Hospitals to the Aged: A Geographic Information Systems Analysis within Illinois. *Health*

Services Research, *29*(6), 629–651.
Martin, D., & Williams, H. C. W. L. (1992). Market-Area Analysis and Accessibility to Primary Health-Care Centres. *Environment and Planning A: Economy and Space*, *24*(7), 1009–1019. https://doi.org/10.1068/a241009
McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In *Frontiers in Econometrics* (pp. 105–142). Berkeley, CA: Academic Press.
Perined. (2017). *Perinatale Zorg in Nederland 2017*. Utrecht. Retrieved from http://www.perinatreg-data.nl/JB2017/Jaarboek2017.html
RIVM. (2018a). *Bereikbaarheidsanalyse SEH's en acute verloskunde 2018: Analyse gevoelige ziekenhuizen*.
RIVM. (2018b). Ziekenhuiszorg | Regionaal & Internationaal | Locaties. Retrieved January 20, 2019, from https://www.volksgezondheidenzorg.info/onderwerp/ziekenhuiszorg/regionaal-internationaal/locaties#node-algemene-en-academische-ziekenhuizen
Tai, W.-T. C., Porell, F. W., & Adams, E. K. (2004). Hospital Choice of Rural Medicare Beneficiaries: Patient, Hospital Attributes, and the Patient-Physician Relationship. *Health Services Research*, *39*(6), 1903–1922. https://doi.org/10.1111/j.1475-6773.2004.00324.x
Van Wee, B., & Van Cranenburgh, S. (2017). Substitutability as a concept to understand travel behaviour and its implications. *Proceedings of the BIVEC-GIBERT Transport Research Days 2017: Towards and Autonomous and Interconnected Transport Future*, 1–18.
Van Wee, B., Van Cranenburgh, S., & Maat, K. (2019). Substitutability as a spatial concept to evaluate travel alternatives.
Wassenaar, S. (2017, March 23). Geen plek in vijf ziekenhuizen voor zieke Wijchenaar. *De Gelderlander*.
Weeda, F. (2018a, October 11). Groeiende wachtlijsten bij operaties. *NRC*.
Weeda, F. (2018b, October 12). Kiezen op IC: de kanker- of de leverpatiënt? *NRC*.