Doctoral theses at NTNU, 2024:28

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Advantages, disadvantages, and unintended side-effects of survey design choices

Doctoral thesis

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Abstract

Travel surveys collect information on travel behavior and are important data sources in transportation planning and modeling. Naturally, the data quality affects the quality of the transport models and analysis, and further, policy and planning; low-quality travel survey data can, at worst, lead to wrong prioritizations in transportation planning and policy. High-quality travel survey data can, at best, provide transportation planners, modelers, and policymakers with a robust basis for decision-making. Thus, it is important to aim for high-quality travel surveys. This thesis aims to contribute to the methodological development of travel surveys. In the thesis, I provide enough information on travel survey methodology so policymakers, planners, students, and others interested in conducting a travel survey can create a survey design based on best practices within the field.

Both qualitative and quantitative methods were used in this thesis. The thesis is based on a document study of national travel survey methodology in Norway, Sweden, Denmark, England, France, and Germany, quantitative analysis of Norwegian National Travel Survey data for the years 2016-2019, an enquête (short survey), multiple data collections with the smartphone app TravelVu, a focus group study and personal interviews.

Data quality was a challenge in all the national travel surveys studied. The countries have attempted to mediate them differently, and all have discussed and/or tested GPS or smartphone solutions. The methodologies vary between countries and are affected by local traditions. An emerging trend is combining data collection tools (i.e., multi-mode solutions). However, mode effects (i.e., data collection tool affecting the data) have been identified in several of the countries that have chosen a multi-mode solution. There are advantages and disadvantages to using different methods in travel surveys. For example, multi-mode solutions can make it possible to get information on more population segments (advantage) but introduce data comparison issues (disadvantage). On the other hand, using one data collection tool reaches fewer population segments (disadvantage), but eliminates data comparison issues (advantage). The choice of method affects the data quality and the nature of the data. Self-reporting methodology gives another type of data than a smartphone-based travel survey, and the best method depends on the segment one wishes to study. Although a smartphone-based travel survey gives detailed data material, results indicate that smartphone-based travel surveys show a lower response rate than traditional methods. The underlying value dimensions of fear of risk and technology interest can explain high nonresponse in smartphone-based travel surveys.

Since different methods give different data types, comparing data across a time where other methods are used should be done with utmost care. However, this does not mean that one should not change the survey design if the current survey design is unsatisfactory. The wish to continue the time series should not be used as an argument for using a survey design that results in low-quality data. To mediate the NTS challenges identified, it is necessary to understand how survey design, data collection tools, and structural changes can affect the data material. If necessary, develop tools and mechanics to reduce potential errors. This demands methodological awareness among those responsible for the NTS, from survey design to data collection and processing. The presented NTS advice can be used to improve the NTS survey design and is based on survey and transportation methodology research.

Sammendrag

Reisevaneundersøkelser samler inn informasjon om reiseatferd og er viktige datakilder i transportplanlegging og modellering. Datakvaliteten påvirker naturligvis kvaliteten på transportmodellene og analysene, og videre politikk og planlegging; data fra reisevaneundersøkelser med lav kvalitet kan i verste fall føre til feil prioriteringer i transportplanlegging og -politikk. Data fra reisevaneundersøkelser med høy kvalitet kan i beste fall gi transportplanleggere, modellere og beslutningstakere et robust beslutningsgrunnlag. Derfor er det viktig å satse på reisevaneundersøkelser med høy kvalitet. Ambisjonen med avhandlingen er å bidra til metodeutvikling innen reisevaneundersøkelsesmetodikk. I avhandlingen presenteres litteratur på reisevaneundersøkelsesmetodikk slik at beslutningstakere, planleggere, studenter og andre interesserte i å gjennomføre en reisevaneundersøkelse kan utforme et undersøkelsesdesign som er basert på beste praksis innen fagfeltet.

Både kvalitative og kvantitative metoder ble brukt i avhandlingsarbeidet. Avhandlingen er basert på en dokumentstudie av nasjonal reisevaneundersøkelsesmetodikk i Norge, Sverige, Danmark, England, Frankrike og Tyskland, kvantitativ analyse av data fra den norske nasjonale reisevaneundersøkelsen for årene 2016-2019, en enquête (kort spørreundersøkelse), en rekke datainnsamlinger med smarttelefon-appen TravelVu, fokusgruppeintervju og personlige intervju.

Datakvalitet var en utfordring i alle de nasjonale reisevaneundersøkelsene som ble studert. Landene har håndtert utfordringene på ulike måter, og alle har diskutert og/eller testet GPS eller smarttelefon-løsninger. Metodene varierer mellom landene og er påvirket av lokale tradisjoner. En voksende trend er å kombinere datainnsamlingsverktøy. En konsekvens av å kombinere datainnsamlingsmetoder er imidlertid at verktøyet kan påvirke datamaterialet, hvilket er en utfordring som har blitt identifisert i flere av landene som benytter en slik løsning. Det er fordeler og ulemper med å bruke ulike datainnsamlingsmetoder i reisevaneundersøkelser. For eksempel kan kombinasjon av datainnsamlingsverktøy gjøre det mulig å samle informasjon om flere populasjonssegmenter (fordel), men introdusere sammenlikningsproblemer (ulempe). På den annen side vil det å kun bruke ett datainnsamlingsverktøy gjøre det vanskeligere å nå alle populasjonssegmenter (ulempe), men eliminerer problemene med sammenlikning (fordel). Valg av metode påvirker kvaliteten til dataene, men også egenskapene. Selvrapportering gir en annen type data enn smarttelefon-baserte reisevaneundersøkelser, og hva som anses som den beste metoden avhenger av hvilket segment en ønsker å studere. Selv om smarttelefon-baserte reisevaneundersøkelser gir et detaljert datamateriale, indikerer resultatene at det også gir

en lavere responsrate enn tradisjonelle metoder. Lav deltakelse i smarttelefon-baserte reisevaneundersøkelser kan forklares av de underliggende verdidimensjonene frykt for risiko og teknologiinteresse.

Siden ulike metoder gir ulike typer data, er sammenlikning over tid der ulike metoder har blitt brukt, noe en bør gjøre med varsomhet. Dette betyr imidlertid ikke at en ikke skal endre undersøkelsesdesign dersom det nåværende designet ikke er tilfredsstillende. Ønsket om å videreføre tidsserien bør ikke bli brukt som et argument for å bruke et undersøkelsesdesign som gir data med lav kvalitet. Dersom vi skal håndtere utfordringene i de nasjonale reisevaneundersøkelsene, er det nødvendig å forstå hvordan undersøkelsesdesign, datainnsamlingsverktøy og strukturelle endringer påvirker datamaterialet, og, om nødvendig, utvikle nødvendige verktøy for å redusere potensielle feilkilder. Dette krever en metodologisk bevissthet hos de som er ansvarlige for de nasjonale reisevaneundersøkelsene, fra valg av undersøkelsesdesign til datainnsamling og dataprosessering. De presenterte rådene kan brukes til å forbedre undersøkelsesdesignet til nasjonale reisevaneundersøkelser og er basert på forskning innen spørreundersøkelsesmetodikk og reisevaneundersøkelsesmetodikk.

Preface

This thesis is submitted to the Norwegian University of Science and Technology (NTNU) in partial fulfillment of the requirements for the degree of philosophiae doctor (Ph.D.).

The main part of the doctoral work was performed at the Department of Civil and Transport Engineering, NTNU, between November 2018 and May 2023, Trondheim. Professor Trude Tørset has been the primary supervisor. Professor Arild Blekesaune has been the co-supervisor.

The Norwegian Railway directorate funded the Ph.D. project. Christine Presterud has been the contact person throughout the thesis work.

Acknowledgements

Thank you to my primary supervisor Professor Trude Tørset. Trude has guided me throughout this Ph.D. period, during good times and more challenging times. Thank you for believing in me and helping me reach the finish line. I would also like to thank my co-supervisor Professor Arild Blekesaune for his supervision, constructive feedback, and advice. Thank you to Jardar Lohne for all you have taught me about academic writing and interdisciplinary work.

Thank you to the Norwegian Railway directorate for providing the resources to make the project possible—additional thanks to Christine Presterud.

Thank you to the smartphone travel survey respondents and those who participated in the qualitative interviews.

Thank you to my colleagues at IBM, especially Ellen H. Flaata and Markus M. Log, for being discussion partners and providing valuable feedback on drafts of papers. Having people to discuss with, especially during the final stages, has been invaluable.

Thank you to Anne Marie Snekvik for the judicial consultation. Thank you to Mimir's Well for their help in setting up a web page for the project.

Thank you to the IBM research assistants Ida Helene Skorge, Signe Bredholt Jørgensen, Andreas Jacques Tangenes, and Kristen Runningen, who assisted me during the data collection. Thank you to Ingrid Runestad for your efforts in the student pilot.

Thank you to Yngve Karl Frøyen for your valuable feedback on the Midway evaluation. Thank you to Hjalmar Christiansen, Lena Hiselius, and Emma Strömblad for your feedback on a draft version of paper II.

Finally, thank you to my friends and family for their support—a special thank you to Tobias. You have been a tremendous support and discussion partner. I am forever grateful.

Trondheim, 2023

Gunnhild Beate Antonsen Svaboe

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Abbreviations

PAPI: paper and pencil interviewing

CAPI: computer-assisted personal interviews

CATI: computer-assisted telephone interviewing

CASI: computer-assisted self-interviewing

CAWI: computer-assisted web interviewing

TS: Travel survey

STS: Smartphone travel survey

HTS: Household travel survey

ITS: Individual travel survey

NTS: National travel survey

NHTS: National Household travel survey

NITS: National Individual travel survey

NNTS: Norwegian National travel survey

UNR: Unit nonresponse

INR: Item nonresponse

GPS: Global Positioning System

PART 1

1 Introduction

Internationally, travel survey researchers face challenges of decreasing response rates, limitations in sampling frames, and growing privacy concerns (Bonnel *et al.*, 2009). At the same time, the data requirements are becoming more complex. Sometimes, new digital technologies are presented as the solution e.g., because they do not rely on human memory (Deng and Ji, 2010) and have the potential to provide more detailed data (Hong *et al.*, 2021). However, there are some challenges connected to them. For example, using smartphones in travel surveys presents challenges regarding privacy (Rubinstein, 2013; Nunan and Di Domenico, 2017) and representativity (Romanillos *et al.*, 2016; Livingston *et al.*, 2021). Furthermore, respondent satisfaction with the instrument (e.g., CAWI, smartphone app, etc.) can affect the data quality (Roddis *et al.*, 2019).

Still, technological developments and developments in survey techniques make it doubtful that survey methods can remain unchanged (Bonnel, 2003). Nevertheless, especially when it comes to national travel surveys, comparability across time is essential, which makes changing methodologies in travel behavior research a challenge. In the early-2000s, Murakami, Morris, and Arce (2003) discussed the benefits of implementing new technology (mobile phones, GPS, internet, personal digital assistants (PDAs), electronic tolling systems, and smart cards) into travel surveys. However, they concluded that even though the technology has great potential regarding data quality, reducing the respondent burden, and reducing sample bias, it cannot replace the need for traditional methods. This indicates that to find the best solutions for future travel survey data collection, it is necessary to both understand the value of traditional methods, and to study potential ways to improve data collection by testing new technologies and methods when they arrive.

Zmud *et al.* (2013) argue that modern economics run on statistics. Thus, decision-makers (politicians, transport authority leaders, etc.) care about travel survey methodology. Furthermore, public authorities sometimes finance (partly or completely) travel survey data collections. For example, travel survey data is used to evaluate and develop the Norwegian National Transport Plans and Byvekstavtalene (Norwegian Ministry of Transport, 2021). High-quality data can give decision-makers the necessary tools to get people and businesses to use the transportation system more efficiently (Zmud *et al.*, 2013). Still, considering how expensive a travel survey can be, it is essential to find the right balance between data quality, quantity, and costs. According to Zmud *et al.* (2013), policy decisions must be based on rigorous and careful analysis using sound and transparent data. There are multiple ways to derive this data, and there is sometimes a tension between methodological innovation and comparability of survey results over time (ibid.).

1.1 Aim and Scope

The work presented in this thesis is focused on daily travel behavior. Still, it is also fundamental research on a field in progress that is relevant for survey methodology practitioners in general. This thesis aims to improve the knowledge of how to make a good research design in a travel survey. Hopefully, the results can contribute to developing practices that provide data material reflecting the population in question. The main ambition is to contribute to the methodological development in the travel survey field. Based on my thesis work, I have illustrated the "travel survey chain" (Figure 1), which is a rough description of the steps in a travel survey from survey design to the use of data. Discussing all aspects of the travel survey chain is too much for one thesis. Thus, I have decided to focus on specific aspects of survey design and the importance of documentation of the process. The reason for focusing on subjects relating to survey design is that by putting in the work in the early stages, the potential for problems with errors in the data at a later stage can be minimized. The subjects I focus on in the thesis, i.e., scope, are in bold in Figure 1.

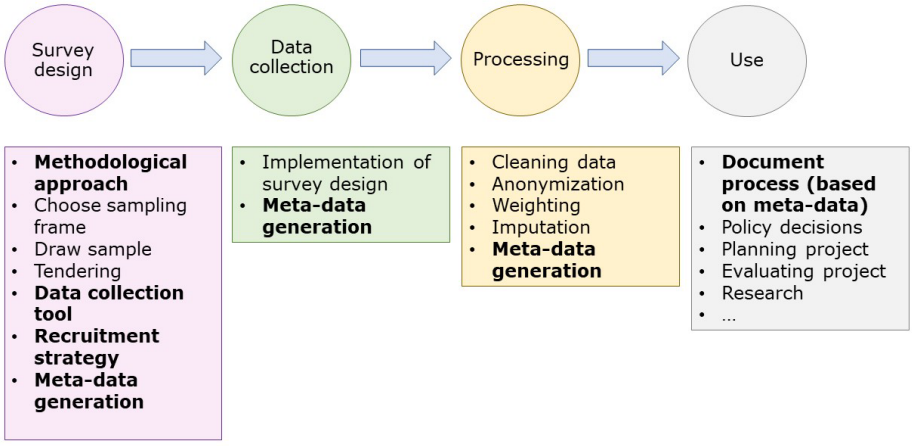

Figure 1 Travel Survey Chain

1.2 Research Questions

Based on the ambition and scope of this thesis, I have formulated three research questions (RQ). The research questions are used to structure the thesis.

RQ 1: What is the current state of national travel surveys?

When answering this RQ, I cover the routine aspect of the state of the art. It is impossible to cover the entire field of NTS within this thesis, but I am ambitious to cover a part of it. The part I cover is the "routine" aspect of data collection, and includes the research design of data collection and choices made on a structural level.

RQ 2: How does using smartphone app technology in travel behavior research affect data quality?

Here, I focus on how changing the technology affects the respondents and who (don't) participate. One of the main challenges, at least the one which has gotten the most attention in current NTSs, is the declining response rates. Thus, it is necessary to find out if changing the method affects this, and if so, why.

RQ 3: What should NTS practitioners do to mediate the challenges regarding NTS quality?

Knowing where we have been is important to give good advice on where to go next. Furthermore, piloting is necessary to get a good idea of how effective a research design is. Thus, I must study previous designs and test alternatives to answer this question. The aim is to be able to give general advice and guidance on the practical level which practitioners can find helpful when planning future travel surveys.

1.3 Plan of the Thesis

Since the research questions are broad, some methodological choices were done when deciding how to contribute to answering them within what was realistic of a thesis. For research question one, I have limited myself to six European countries chosen because they were comparable to the Norwegian NTS. For research question two, I mainly studied smartphone apps developed to collect travel survey data. Furthermore, I focus on how this affects participation. Regarding the third research question, I advise on the challenges identified and studied in the papers.

These choices mean that we have not studied all countries and all NTSs in the world, have not tested all ways of utilizing smartphones in a travel survey, nor identified or studied all challenges in NTSs. In the discussion, I discuss the potential consequences of these choices.

1.4 Papers

The papers that contribute to answering the three research questions are briefly described in this section. I have structured them in a list based on how they answer the research questions, not the order in which they were written (i.e., chronologically). In simple terms, the strategy of this thesis is "troubleshooting travel surveys." First, I present a paper studying the current situation of the Norwegian National Travel Survey (NNTS), and here I identify some challenges. Then, I attempt to put this in an international context in paper II while also looking for potential solutions in other countries. Paper I and II are methodological reviews – they present how travel surveys are conducted today, the consequences of choosing the different survey designs, and identify the challenges and benefits of conducting travel surveys using the presented methods. In paper III, I present results from testing an alternative way of collecting travel survey data, focusing on recruitment. I discuss alternatives to the current way of conducting a travel survey (smartphones), while also identifying challenges regarding recruitment. In paper IV, I troubleshoot the recruitment challenges and explain why some find smartphone travel surveys problematic and why people respond differently to digital technology. Paper IV contributes to understanding the recruitment effects of changing to a smartphone solution. Figure 2 illustrates the process of the thesis.

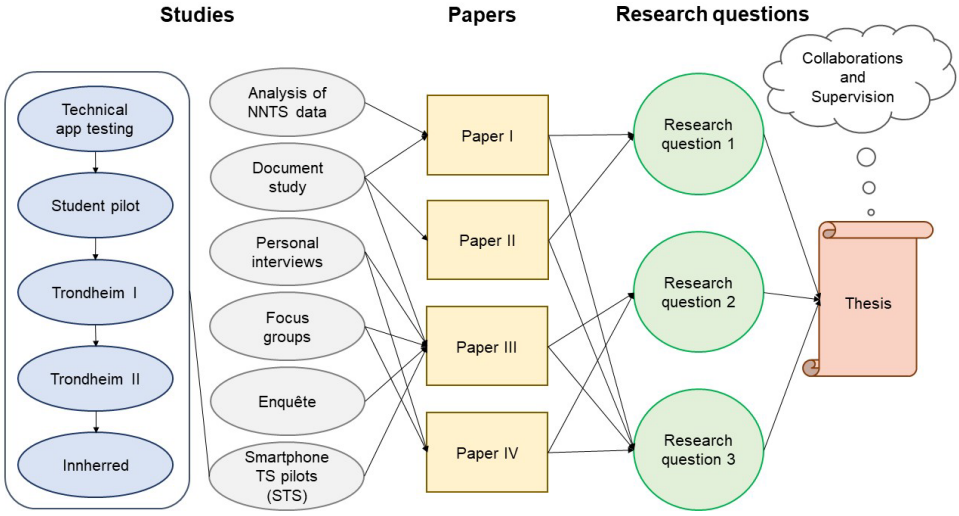

Figure 2 Thesis process

1.4.1 Paper I: The Decline of the Norwegian National Travel Survey Empire

Svaboe, G. B. A., Tørset, T. and Lohne, J. (forthcoming). The Decline of the Norwegian National Travel Survey Empire. Transportation Research Procedia.

Paper I presents a historical overview of trends and challenges in the Norwegian National Travel Survey (NNTS). Method: document study and quantitative analysis of NNTS data for 2016-2019. The paper was written in 2021-2023 and was presented at the 12th International Conference on Transport Survey Methods in Portugal in March 2022. Paper I has been accepted for publication and will be published in Transportation Research Procedia.

This paper will contribute to answering research questions 1 and 3.

Author contributions:

Gunnhild B. A. Svaboe: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing – original draft, Writing – review and editing, Visualization

Trude Tørset: Conceptualization, Writing – review and editing, Supervision

Jardar Lohne: Conceptualization, Writing – review and editing, Supervision

1.4.2 Paper II: A Comparative Study of National Travel Surveys in Six European Countries

Svaboe, G. B. A., Tørset, T. and Lohne, J. (XXXX). A Comparative Study of National Travel Surveys in Six European Countries. Submitted to Transportation Planning and Technology.

A paper describing methodological choices, trends, and challenges in the national travel survey in Norway, Sweden, Denmark, England, France, and Germany. Method: document study of six European national travel surveys. Paper II was written in 2022-2023 and submitted to Transportation Planning and Technology in September 2023. The version included in the thesis is the revised version, which was submitted in December 2023. It is currently under review.

This paper will contribute to answering research questions 1 and 3.

Author contributions:

Gunnhild B. A. Svaboe: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing – original draft, Writing – review and editing, Visualization

Trude Tørset: Conceptualization, Writing – review and editing, Supervision

Jardar Lohne: Conceptualization, Writing – review and editing, Supervision

1.4.3 Paper III: Recruitment strategies in app-based travel surveys: Methodological explorations

Svaboe, G. B. A., Tørset, T. and Lohne, J. (XXXX). Recruitment Strategies in App-Based Travel Surveys: Methodological Explorations. Submitted to Transportation Research Part A: Policy and Practice.

Paper III presents the results from multiple studies concerning the use of smartphone tracking technology in travel surveys while also discussing this in the context of traditional methods in travel survey methodology. Method: document study, enquête, 2 qualitative interview studies and pilots with TravelVu. Paper III was written in 2021 and submitted to Transportation Research Part A: Policy and Practice in December 2021. The first version of this paper has been available online as a preprint since December 2021 (Svaboe, Tørset, and Lohne, 2021). The paper included in this thesis is a revised second submission, which was submitted in May 2022. It is currently under review.

This paper will contribute to answering research questions 2 and 3.

Author contributions:

Gunnhild B. A. Svaboe: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing – original draft, Writing – review and editing, Visualization

Trude Tørset: Conceptualization, Methodology, Formal analysis, Investigation, Critically reviewing, Writing – review and editing, Supervision

Jardar Lohne: Formal analysis, Writing – review and editing, Supervision

1.4.4 Paper IV: Understanding skepticism of smartphones in travel behavior research: A qualitative approach

Svaboe, G. B. A., Blekesaune, A. and Tørset, T. (2023). Understanding skepticism of smartphones in travel behavior research: A qualitative approach. Transportation Research Interdisciplinary Perspectives, 22 (100935), https://doi.org/10.1016/j.trip.2023.100935

Paper IV aims to improve the understanding of human reactions to technology by identifying underlying value dimensions. Method: a thematic analysis of data from two qualitative interview studies. Paper IV was written in 2022 and submitted to Transportation Research Interdisciplinary Perspectives in January 2023. It was accepted in September 2023. The version included in the thesis is the published version.

This paper will contribute to answering research questions 2 and 3.

Author contributions:

Gunnhild B. A. Svaboe: Conceptualization, Data Curation, Formal Analysis, Methodology, Visualization, Writing – original draft, Writing – review and editing

Arild Blekesaune: Conceptualization, Writing – review and editing, Supervision

Trude Tørset: Writing – review and editing, Supervision

1.5 Collaborations and Supervision

1.5.1 SmartRVU

The thesis work started in November 2018, but the project and story of 'SmartRVU,' including my involvement and interest in the subject, started in November 2016. In 2016, I got a job as a research assistant at the Department of Civil and Environmental Engineering (IBM) at NTNU. My main job was to study the potential and use of smartphones in travel surveys. After the contract ended, we understood that there was a lot of work unfinished. Fortunately, the Norwegian Rail Directorate agreed and financed my Ph.D. Candidate position.

The thesis work was conducted while I was part of a group called SmartRVU, which consisted of myself and three other Ph.D. candidates. The group is led and supervised by Trude Tørset. I began working on my Ph.D. before the two other candidates. 2 new Ph.D. candidates began in the summer/fall of 2019, and one Ph.D. candidate began in 2020. Thus, I have cooperated with two Ph.D. candidates during data collection in "Trondheim II" (second TravelVu data collection of 2019) but not "Trondheim I" (first TravelVu data collection of 2019).

1.5.2 Collaboration with Trøndelag fylkeskommune

One crucial data collection with TravelVu was done in the area Innherred in collaboration with Trøndelag fylkeskommune (TFK). TFK and SmartRVU collaborated on the research design, but TFK was responsible for collecting data. A more detailed description of the methodology during data collection is in the methodology chapter, paper III and TFK's report (Overvik *et al.*, 2020).

It was interesting collaborating with an external institution. Furthermore, it made possible one extra data collection and more experiences with recruitment in smartphone-based travel surveys.

1.5.3 Travelviewer – data for low-carbon sustainable transport systems

During the Ph.D., the SmartRVU group represented Norway in an EU project (ClimateKIC) called *Travelviewer* (Indebetou, no date; Hubrich *et al.*, 2020). The project started in September 2018 and ended in September 2020. Climate-KIC co-financed Travelviewer, which tested the app TravelVu in four countries: Denmark, Norway, Germany, and Italy. The project aimed to create a new service called "Travelviewer", where one could view details of local TS online.

In the Travelviewer project, I collaborated with Trivector and met representatives working with travel survey methodology from Denmark, Germany, Italy, France, and England. Travelviewer pilots with TravelVu were conducted in Norway (in this thesis, I refer to the Travelviewer data collection as “Trondheim II”), Denmark, Germany, and Italy. We met at seminars, where we discussed our findings and shared experiences. The results from Trondheim are documented in reports (Tørset and Svaboe, 2020c, 2020a, 2020b).

1.5.4 Supervision

I helped co-supervise two master's students (Runestad, 2018; Vestgård, 2019) during my thesis work. These experiences provided valuable additional perspectives on recruitment and the effects of methodological choices. Results from the Student Pilot were presented at the 2018 European Transport Conference (ETC), and experiences from Vestgård’s data collection influenced my perspective on recruitment, and thus, paper III. Part of Vestgård’s master’s thesis was turned into a journal article on cycling under the influence (Vestgård *et al.*, 2021).

1.6 Structure of the Thesis

In Chapter 2 (Background), I present relevant literature on travel survey methodology and a bit of travel survey history. This results in a discussion of knowledge gaps (2.14). In Chapter 3 (Methodology), I present a more detailed description of my methodological choices and discuss potential limitations. I give a more detailed description of the process than was possible in the papers and describe the reasoning behind the choices. In Chapter 4 (Results), I summarize the results based on the papers. In Chapter 5 (Discussion), I discuss the results in the context of Chapter 2. It is structured after the research questions which I aim to answer in this chapter. In Chapter 6 (Conclusion), I summarize the main findings and present some recommendations.

2 Background

A consistent trend in the feedback from reviewers throughout the process has been a wish to get a better overview of existing research on travel survey methodology to identify the absolute novelty of the approaches proposed. Thus, I aim to give the reader at least an introduction to (national) travel survey methodology in this chapter.

The background chapter includes literature from the papers and explains some topics more in-depth than was possible in the papers. I have chosen to go more in-depth on specific issues in survey design planning because details decided during the planning phase of a travel survey can affect the data. I also include some new information; In the papers, I argue that there is a lacking methodological awareness. During the midway evaluation, I was asked about what the literature says about errors in modeling due to survey design choices (sampling, data collection tools, etc.). However, there has not been enough room to go into detail on each methodological problem on a statistical level. For example, I discuss the issue of nonresponse in paper I and II. Thus, the statistical challenge of item nonresponse and unit nonresponse and the difference between them is explained in more detail in this chapter. Furthermore, I give the reader more literature on the history of travel surveys that were not included in the papers either because it was more focused on panels (e.g., MOP or Dutch Mobility Panel) or geographically far away (e.g., Australia). The literature has influenced the travel survey methodology development discussion and is thus included here to discuss the knowledge gap (2.14).

2.1 Purpose of Travel Surveys

There are no set standards for questions in travel surveys. Still, most travel surveys aim to collect information about some key elements of the trips (such as origin and destination, transport mode, duration, etc.) (Ortúzar and Willumsen, 2011, p. 71). It is also common to include some sociodemographic background questions about the respondent. It is important to include questions about sociodemographic and socioeconomic characteristics because studies (Domencich and McFadden, 1975; Ben-Akiva and Lerman, 1985) have shown that factors such as age, gender, education, occupation, etc., can affect travel behavior. Travel survey data on daily travel is mainly used for transport modeling and making predictions, which in turn is used in the policy decision-making process, i.e., transport planning.

There is no one definition of a *national* travel survey. However, most of the NTSs collect information about personal travel, some socioeconomic background information, and the availability of modes of transportation (Kunert, Kloas and Kuhfeld, 2002, p. 107). In Norway, the more extensive local travel surveys are often connected to the NTS because the

counties and municipalities can buy additional samples during the data collection (Hjorthol, Engebretsen and Uteng, 2014). These can be used to get a larger sample for the smaller geographical areas in Norway. Local travel surveys can be conducted because of specific actions or projects, such as in conjunction with building a bridge or new cycling road, or to make prognoses before starting a project in a limited geographical area. The purposes vary and the travel surveys are conducted by both private and public institutions.

2.2 Travel Survey Sampling Strategies

Regarding NTS sampling strategies, most NTSs use random sampling with geographical stratification (Armoogum *et al.*, 2014). Stratification is a sampling strategy to ensure critical subgroups are represented in the data material (Groves *et al.*, 2009; Ringdal, 2018) and can produce more detailed and representative samples (de Vaus, 2014). However, the stratification procedure can be complicated. The sample is only representative if group proportions in the sample are equal to the proportions in the population (de Vaus, 2014). The requirement of representativeness is not always met due to chance, causing sampling error. Furthermore, successful stratified sampling (from a representativity perspective) requires unbiased sampling frames that are not always available nationally.

There are two types of stratification (Ringdal, 2018): In *proportional stratification*, the strata proportion sizes reflect the proportion sizes in the population. In *disproportional stratification*, the strata proportion sizes do not reflect the proportion sizes in the population, and it is used to analyze critical subgroups in the sample (Ringdal, 2018). In stratified samples, sample weights are expected to be created to correct bias in distributions. However, weighting can become challenging if the strata are combined while biased in different ways (e.g., if the means of the various strata fall on different sides of the mean one tries to correct for (Moser and Kalton, 1971)). In that case, when attempting to fix the distributions using weights, one may increase bias in the sample.

In European NTSs, stratified random sampling (i.e., segmenting the population in subpopulations/strata in a sampling frame and selecting a sample from each list) or uniform random sampling (i.e., sampling units are selected from a sample frame, and each element has the same probability of being chosen) is most common (Armoogum *et al.*, 2014, p. 54; de Vaus, 2014). Regional add-ons are sometimes used to say something more substantial about specific areas or groups and are used in, e.g., the NNTS (Grue, Landa-Mata and Flotve, 2021) and German NTS (MiD) (Hauslbauer, Schade and Petzoldt, 2022). Grue, Landa-Mata, and Flotve (2021, p. 11) problematize and discuss the side effects of add-ons (i.e. disproportional sampling) in the 2018/19 key report. Although add-ons were not introduced until the 1997/1998 NNTS, they were discussed before the first NNTS.

According to Bolkesjø and Solheim (1984), regional add-ons were argued to be a good idea because few registered trips with specific modes (public transport, flying, and rail). They considered oversampling the larger cities but decided not to due to practical and economical reasons.

2.3 The Trade-off: Quality, Quantity, and Cost

According to Richardson *et al.* (1996), the trade-off between cost, quantity, and quality (as described in paper II) is not independent of the respondent because, in general, the longer the survey, the lower the response rate (the response rate decrease depending on respondent's interest in the survey and the quality of instrument design). Thus, there is a point where an increase in questions in the questionnaire will lead to a decrease in responses (quantity).

Cost is also connected to the method. Travel surveys are sample surveys, but the "best practice" data collection method varies greatly between countries and has changed over time. According to Stopher (2009b), it is essential to keep in mind two keywords when considering a method: "representative" (we should aim to get a sample that is as representative as possible for the population we wish to study) and "accurately" (the survey instrument should be good enough to provide reliable results).

2.4 Cross-sectional Travel Surveys

Cross-sectional travel surveys have larger samples drawn independently over different years or spread over the year (Ortúzar *et al.*, 2011). The advantages of cross-sectional surveys are that they are cheaper, give a larger sample, are easier to recruit to, and demand less interviewer training (Ortúzar *et al.*, 2011). The drawback of cross-sectional travel surveys is that one respondent's travel behavior at one point is not enough to get a realistic description of long-term trends or changes in individual behavior (Ortúzar *et al.*, 2011).

Some cross-sectional surveys collect data for multiple days but are not panels (they do not have waves). This includes, for example, the English NTS (Department for Transport, 2020a) and Mobility in Germany (MiD) (Eggs *et al.*, 2018).

Some cross-sectional travel surveys, such as the Sydney HTS (Ampt, Ortúzar and Richardson, 2009), the NNTS (Grue, Landa-Mata and Flotve, 2021), and Danish NTS (Center for Transport Analytics, 2022), have continuous data collection. Continuous data collection means that the survey takes place throughout the year, usually with data collection on all days of the week and all weeks of the year, and continues for multiple years (Stopher, 2009b). That way, it is possible to collect information from all the seasons

and all weekdays, despite not doing a panel survey. Furthermore, continuous data collection allows continuity in the project management staff, training and maintaining highly skilled interviewers, and monitoring their performance (Ampt, Ortúzar and Richardson, 2009; Bonnel *et al.*, 2015). The perceived trade-off is that continuous TSs usually have smaller annual sample sizes (Raimond, 2009).

2.5 Panel Travel Surveys

Panel travel surveys have smaller samples, and the respondents are interviewed multiple times over a more extended period, ideally for years (Ortúzar *et al.*, 2011). Examples of extensive panel surveys in mobility research currently running are the German Mobility Panel (MOP) (Eisenmann *et al.*, 2018) and the Dutch Mobile Mobility Panel (Geurs *et al.*, 2015). Another large-scale panel is the US Puget Sound Transportation Panel (PSTP) which ran ten waves between 1989-2002 (Murakami and Waterson, 1990; Murakami, Greaves and Ruiz, 2006). In Adelaide, Australia, a three-year household panel was conducted in 2004-2007 (Stopher and Swann, 2008) and a three-wave GPS-based panel in 2005-2007 (Stopher *et al.*, 2010).

The main advantage of panel surveys is that it makes it possible to study both inter- and intra-personal variance[1], and they can capture long-term effects on travel behavior (Murakami, Greaves and Ruiz, 2006; Axhausen *et al.*, 2007). Moreover, according to Madre (2003), it is necessary to collect information over several weeks surveying the same individuals to observe changes in travel behavior. Stopher and Zhang (2011) found a substantial variation in travel behavior, which cannot be captured with only one day of reporting per individual. Panel surveys are, however, quite expensive, and recruitment is more challenging since the respondent burden is higher, and there is a risk of attrition (dropping out) (Murakami, Greaves and Ruiz, 2006). It is also possible to conduct short survey panels, or multi-day data collections, where the same units are registered for multiple days (for example, a week) but not repeated for various years (Axhausen *et al.*, 2002, 2007).

2.6 Individual Travel Surveys (ITS) versus Household Travel Surveys (HTS)

According to Armoogum *et al.* (2014), in an individual travel survey (ITS), the individual is the highest statistical unit interviewed. Examples of ITSs are the national travel surveys in Norway, Sweden, Netherlands, Denmark, and Finland (Armoogum *et al.*, 2014). The household is the highest statistical unit interviewed in a household travel survey (HTS).

[1] Interpersonal variance is variance in travel behavior between individuals and intrapersonal variance is an individual's day-to-day variability in travel behavior (Pas, 1986, 1987).

Examples of HTSs are the German Mobility Panel (MOP), Mobility in Deutschland (MiD), and the British National Household Travel Survey (Armoogum *et al.*, 2014).

Household travel surveys are generally seen as the standard way to conduct travel surveys, and most research has been published on household travel surveys. However, there are variations regarding the specifics of survey design. For example, in MiD, all household members are interviewed. In the French NTS, often called an HTS, only one household member is interviewed on travel behavior and asked to report trips. To complicate further, the definition of a household varies from country to country. For a more detailed explanation of the differences and variants and discussions of the advantages and disadvantages of HTS versus ITS, see Armoogum *et al.* (2014), Hubrich *et al.* (2018), and Stopher *et al.* (2006).

For this thesis, I differentiate between HTS and ITS in a definition close to Armoogum *et al.*'s (2014) definition but not identical; I also require that the highest statistical unit reports daily trips. By this, I mean that in an HTS, all household members must report daily trips, and in an ITS, the sampled person must report daily trips. For this reason, I treat the French NTS as an ITS in paper II and this thesis.

2.7 Data Collection Methods

Below I briefly describe different methods to collect travel survey data. It should be noted that there is no universal agreement about the benefits and drawbacks within the travel survey community regarding the different methods. It is impossible to include all factors and all the contradictory opinions in the literature within travel survey methodology and survey methodology in general. Thus, I include what I consider to be the most critical factors regarding each method in the context of my thesis. However, it is not an exhaustive description or list of methods and combination of methods.

2.7.1 Traditional Methods

Face-to-face interviews are the most traditional way to collect travel survey data (Paskota, 2006). Face-to-face travel surveys (PAPI or CASI) are conducted using interviewers who interrogate one or more persons (Bonnel, 2003). It is generally considered to be the most expensive method. In postal travel surveys, the respondent receives the questionnaire by post, self-administers the responses, and later returns it, thus eliminating the need for an interviewer. These surveys are generally considered to be the least expensive of the traditional methods (Bonnel, 2003). A third conventional form of travel survey is the telephone survey (CATI). In the telephone survey, an interviewer interviews the respondent over the telephone, usually at home. Although CATI makes it possible to reach a larger geographical area and is cheaper than face-to-face interviews, it is easier to decline

participation than face-to-face interviews and works best for shorter questionnaires (de Vaus, 2014; Ringdal, 2018). Internet surveys (CAWI) make it possible to include visual and audio information; it is possible to reach a larger geographical area at lower costs (Morris and Adler, 2003; Groves *et al.*, 2009). Usually, nonresponse is a more significant issue with internet surveys than with the other aforementioned traditional methods (de Vaus, 2014).

Interviewers are central in traditional travel survey methods, both as data collectors (e.g., face-to-face interviews, telephone interviews) and motivators. Chapleau (2003) studied quality in the Montreal CATI HTS and found that the interviewer's experience was the most relevant factor affecting quality and productivity. There are both positives and negatives to having an interviewer because the interviewer can affect the interviewee's responses (i.e., interviewer effect), mainly if the survey includes sensitive questions about attitudes and opinions (Bonnel, 2003). However, the interviewer can motivate a response, clarify misunderstandings, answer questions, and hold the respondent's attention.

2.7.2 From GPS-based Travel Surveys to Smartphone Travel Surveys

Smartphone apps have gotten a lot of interest within the travel survey community. This is not surprising, considering that every smartphone owner in practice carries their movement tracker. Even though smartphones are relatively new, global positioning systems (GPS) have been used in travel surveys for many years. Here I present some studies on the use of movement-tracking devices (GPS devices and smartphones) in travel surveys and their pros and cons.

2.7.2.1 Noteworthy Travel Surveys Using GPS Devices and Smartphones

Several of the early, high-profile travel surveys using new technology were conducted in USA and Australia. According to Stopher *et al.* (2010), GPS was first trialed in the mid-1990s as a direct result of a Conference on HTS in Irvine, California. In 1996, an HTS using GPS devices was conducted in Kentucky, USA (Wagner, Murakami and Guindon, 1997). Wolf (2000) studied the potential of replacing travel diaries with GPS data loggers. Wolf found that most trips can be found, although short stops could be challenging to identify. Wolf suggested that these could be recorded through follow-up or using geographic information systems (GIS). In 2001, the California Statewide Travel Survey GPS Study was conducted, where 292 households completed a multi-mode CATI/GPS travel survey (Wolf *et al.*, 2003).

Large-scale GPS-based travel surveys have been conducted in Australia since the 2000s (Stopher and Swann, 2008; Stopher *et al.*, 2010). According to Swann and Stopher (2008), using GPS devices in travel surveys reduces the respondent burden and makes it possible

to collect higher-quality data for multiple days. Furthermore, the authors argue that due to Australia's relatively high civic and institutional trust, a reasonable share of people is willing to participate in a GPS TS (Swann and Stopher, 2008).

Another famous smartphone-based TS is the *Future of Mobility Study* (FMS), conducted in Singapore in 2012 (Cottrill *et al.*, 2013). A subsample (1000 persons) of the Singaporean Household Interview Travel Survey used an app for five days. The FMS did not achieve a representative sample due to recruitment challenges, partly due to participation requirements (owning a smartphone and having the necessary skills to report travel). Young adults with high education and low car ownership were overrepresented in their pilot. Interestingly, some respondents continued to log their travel behavior beyond the requested time. The authors theorize that this was due to participant interest in the survey process or that they found it interesting to log and have a record of their activities (Cottrill *et al.*, 2013).

Safi *et al*. (2017) compared four technology-based travel survey methods (ATLAS II smartphone app, web-based survey, handheld GPS, and GPS data from smartphones) with the New Zealand NHTS. They found that smartphones can enhance the accuracy of data. However, an increased participation burden affects the data quality, including lower trip rates. Of the methods tested, they found that ATLAS II gave the highest quality data and that different demographics had different preferences in data collection tools (e.g., younger participants were more interested in smartphone-based data collection, and those with the highest income were most interested in ATLAS II).

GPS and smartphones have been tested nationally in Europe since the mid-2000s. The Dutch Mobility Panel uses smartphones to monitor movement (Geurs *et al.*, 2015; Thomas *et al.*, 2018). It has also been multiple GPS pilots connected to NTSs. GPS tracking was an option for respondents in the French NTS in 2007-2008 (Armoogum *et al.*, 2014). Trafikanalys did pilots with smartphones and mobile cell phone data in 2016-2018 but concluded that the disadvantages outweighed the advantages (Saxton, 2018b). In 2010, the Department for Transport (DfT) began preparing a pilot with the primary objective of investigating whether a GPS solution would reduce the burden of the English NTS. It started a pilot in 2011 with sub-samples of the primary NTS sample (Sneade, 2013). The pilot conclusion was that GPS was unsuited for the NTS because the data did not resemble the traditional diary outputs.

2.7.2.2 Pros and Cons of Using Tracking Technology in Travel Surveys

The main advantage of GPS devices and/or smartphones is that they provide higher detail data (Hong *et al.*, 2021), do not rely on human memory (Deng and Ji, 2010), and can be

used to correct potential errors and misreporting in self-completion travel surveys (Sammer *et al.*, 2018). Lynch *et al.* (2019) argue that an HTS smartphone solution could result in more accurate trip rates. According to Sammer *et al*. (2018), underreporting of trips can be mediated by using GPS solutions.

The problem with implementing smartphones as a part of data collection in travel surveys are privacy issues (Rubinstein, 2013; Nunan and Di Domenico, 2017; Julsrud and Krogstad, 2018) and representativity issues (Romanillos *et al.*, 2016; Saxton, 2018b; Livingston *et al.*, 2021). In the context of national travel surveys, there is the added challenge of data comparability across years. GPS data does not provide data equivalent to traditional methods (Sneade, 2013). According to Sammer *et al.* (2018), the main problem with GPS in travel surveys is that about half of those willing to participate in a traditional travel survey would consent to a GPS travel survey. Further, Stopher *et al.* (2010) have hypothesized that those who use a GPS to track their movement in a travel survey are more conscientious and better at describing their mobility. Another drawback is that GPS surveys have a higher risk of overreporting trip length and duration than traditional surveys (Sammer *et al.*, 2018). Kelly *et al.* (2013) reviewed studies comparing self-reporting of trips with GPS surveys and found that self-reported trips were longer than the GPS trips, and the GPS surveys reported a higher number of trips. A general challenge in smartphone-based travel surveys is low participation rates. Silvano *et al.* (2020) tested recruitment methods and found that the smartphone-based method produced the lowest response rates.

Furthermore, research (Milne and Watling, 2019; Lee and Sener, 2020; Seifert, Cotten and Xie, 2021; Cronley *et al.*, 2023) shows that different population segments use mobile phones and the internet differently. Thus, it is necessary to know how this can affect the data when choosing a smartphone solution. There are also differences in travel behavior among respondents reporting travel using traditional methods (e.g., online questionnaire, telephone interview) and smartphone solutions. For example, studies (Flake *et al.*, 2017; Lynch, Dumont and Greene, 2019) show that the daily trip rates are higher (15-18 percent) amongst smartphone users than the trip rates of respondents using traditional methods. Furthermore, Lynch *et al.* (2019) found that a lower share (4-6 percent) of smartphone users were immobile (zero trips on the day of reporting) than respondents using traditional methods (25 percent).

2.7.3 Multi-mode Solutions to Data Collection

Multi-mode data collection (i.e., using multiple methods to collect data) has become quite popular. A multi-mode solution has been implemented in Norway (Grue, Landa-Mata and

Flotve, 2021), Denmark (Center for Transport Analytics, 2019), Sweden (Viklund, 2021), and Germany (MiD and MOP) (Eggs *et al.*, 2018; Gruschwitz *et al.*, 2018). The main advantage of combining methods is that it can reduce some methods' drawbacks while utilizing others' strengths (Paskota, 2006). There are, however, challenges with combining and/or comparing different data sources because methodological differences can affect the data (Morris and Adler, 2003). Mode effects appear if the method used affects the responses (de Vaus, 2014) and is a risk in any survey, but is more challenging to deal with if one combines methods for comparability reasons. Perhaps the SHANTI project was the largest attempt at comparing different types of data sets, comparing key numbers from multiple national travel surveys in Europe (Armoogum *et al.*, 2014).

Bayart and Bonnel (2015) studied the respondent and non-respondent sociodemographic characteristics and travel behavior in an HTS combining survey methods (web, telephone, and face-to-face) in Rhône-Alpes. The households answering the web survey had fewer trips than those that answered by phone. They explain this by a higher share of immobility and fewer trips, and mainly the short trips are omitted. Web respondents also belonged to larger households and had a higher income, education level, and occupation group. At the 12th ISCTSC, Bayart and Bonnel (2022) presented a paper on potential ways to mediate challenges using multi-mode data sets. They compared travel behavior from three experiments in France from data collected using face-to-face interviews, CAWI, and CATI. They found that the number of trips for CAWI respondents was lower than face-to-face and CATI respondents, and that the short trips with a less constrained trip purpose are “missing”. The authors hypothesize that the absence of an interviewer could explain the omission of trips.

Christensen (2013) studied the effect of adding CAWI to the (previously) CATI-based Danish NTS and found that introducing CAWI can reduce costs, that more trips are reported with CAWI, and that it increases the participation rate of children and highly educated people. According to Christensen (2013), the weighting procedure can compensate for differences in response shares. However, it was not possible to compensate for everything (Christensen, 2013). Christensen (2013) studied how the respondents varied regarding response rates and travel behavior. Regarding response rates, CAWI is more useful in the following cases: 1) when the respondent needs the flexibility to answer at a time that suits them, 2) when interviewing highly educated people and university students, and 3) for interviewing schoolchildren and teenagers. On the other hand, CATI is better for the following respondents: 1) older people 2) those not inclined to answer CAWI 3) respondents with few socioeconomic resources. Regarding travel behavior, Christensen (2013) found

differences between CAWI and CATI for the share of immobile respondents, but according to the author, this could be explained by differences in socioeconomic variables.

Murakami *et al.* (2003) discuss the positives and negatives of using new technology in travel surveys, such as GPS devices and mobile phones. They point out how young adults and those with a high disposable income often adopt new technologies. However, young males have traditionally been a relatively large part of the group of non-responders in traditional travel surveys, so using new technologies can mediate the underrepresentation of this group. According to Murakami *et al.* (2003), these findings support using complementary methods to address the fact that different population segments prefer other methods. However, data comparability and not changing respondent travel behavior while collecting data (unless that is the point) is essential.

2.8 Unit of Analysis

The unit of analysis in travel surveys is usually households, persons, and/or trips. Besides the households/individuals, the 'trip' is arguably the most essential unit of analysis for the travel behavior researcher. The trip is the basic unit of travel (Armoogum *et al.*, 2014), and thus essential to register correctly. Generally, a trip is a one-way journey from an origin to a destination, with a single activity or purpose. Trips can include multiple modes of transport and vary in length and duration.

The definition of a trip and how it is measured varies between countries, and perceptions of what constitutes a particular type of trip change over time. Thus, data harmonization should be done with the utmost care (Wittwer *et al.*, 2018). A challenge regarding the trip definition is that respondents perceive and remember trips differently based on how the question is formulated and the method used to collect the data (Saxton, 2018b). Thus, the data collection method and the interviewer can affect the trip length and the number of trips reported. Furthermore, this challenges comparability when changing data collection methods, especially when comparing data from GPS devices or smartphones to self-reported travel behavior.

Some respondents do not understand the definition of a trip, as it is used in a transport planning context (Stopher, Prasad and Zhang, 2010). Still, the travel behavior researcher can not expect this either. Thus, creating a survey design in which the respondent reports their travel as correctly as possible is important. If the respondent does not understand the definition of a trip, this will naturally affect the accuracy of the trip rates and, further, the validity of the data.

In this thesis, I operate with the trip definitions presented in Table 1.

Table 1 Trip definitions (source: Appendix C in paper II)

Country	Definition
Norway	A trip is defined as any movement outside one's own home residence, school, workplace or holiday home, regardless of distance, duration, purpose or mode of transportation (Grue, Landa-Mata and Flotve, 2021, p. 2).
Sweden	A round trip (helresor) is a sequence of movements with one or more modes of transport in which one or more errands are carried out and which ends at the workplace, school, place of residence or other accommodation (Holmström, 2021, p. 2). Part trips (delresor) are movements between places where a respondent does an activity, and multiple modes of transport can be used (Saxton, 2018a, p. 15).
Denmark	A trip is defined as transport from one place to the next, with one or more modes of transport (Christiansen and Baescu, 2020, p. 5).
England	A trip is defined as a "one-way course of travel with a single main purpose" (Department for Transport, 2020b, p. 9).
France	A trip is a movement within 80 km radius of their own home (Guennec, 2012, p. 10).
Germany	A trip is defined as "a movement from origin to destination including possible stops and changes in modes of transport" (Follmer and Gruschwitz, 2019, p. 6).

2.9 Challenges in Travel Surveys

Here I present three challenges prominent in national travel surveys: nonresponse, respondent burden, and structures affecting data. This is not an exhaustive list of challenges, and they are not independent of each other (e.g., respondent burden can affect nonresponse). They are, however, three crucial challenges, two of which are among the most discussed in the literature (nonresponse and respondent burden) and one of the least discussed (how structural changes can affect the data). The following three subchapters explain how the presented challenges are connected to survey design, and further, outcome (i.e., travel survey data). I go into more detail on how literature suggests mediating these challenges in sections 2.10.-2.12.

2.9.1 Nonresponse

According to Richardson, Ampt and Meyburg (1996), it is crucial to deal with nonresponse because nonrespondents are from segments with different sociodemographic characteristics and a different travel behavior than respondents. Thus, reducing nonrespondents reduce the survey bias and increase the accuracy of estimates. Understanding how survey design affects the data is important because nonrespondents' characteristics vary depending on the methodology chosen (Richardson, Ampt and Meyburg, 1996). Furthermore, travel behavior and nonresponse are connected; people with high mobility rates are less likely to participate in HTSs (Richardson, 2000; Stopher *et al.*, 2006). The best solution to nonresponse is to make plans before data collection starts to reduce nonresponse as much as possible (Richardson, Ampt and Meyburg, 1996).

The issue of nonresponse can be divided into multiple groups because there are different ways to deal with them. *Non-contacts* are those where the interviewer/researcher fails to contact a sampled respondent (Zmud, 2003). A challenge with non-contacts is that it can

be difficult to identify why the respondent does not respond (the telephone number or address can be invalid, the respondent could be screening the call, the person/household is rarely available, etc.). Furthermore, non-contacts are costly because there are multiple contacts without any response. According to Zmud (2003), non-contacts represent demographic subgroups with an 'on-the-go lifestyle', making them hard to reach because they are usually too busy to participate or unavailable when contacted. This can cause bias in the sample because these subgroups could have a high mobility rate. Thus, their participation could affect the trip rate estimations.

Suppose the interviewer gets in contact with a household or person over the phone. In that case, most refusals occur within the first minute, which means that the interviewer has enough time to present themselves, but not enough to give important information about the purpose of the study (Zmud, 2003). Thus, the introduction of the interviewer is crucial for minimizing refusals in TSs using interviewers. The generally accepted practice is to keep the introductions short and to give a two-sentence description of the study. In conjunction with the 1995 Conference on Household Travel Surveys in Irvine, California, Richardson *et al.* (1996) wrote a resource paper on nonresponse. The authors highlighted some of the most prevalent issues regarding nonresponse. Two of them are especially relevant in the context of the thesis (Richardson, Ampt and Meyburg, 1996, p. 112):

- Nonresponse issues must be considered within the framework of an overall systemic approach to conducting travel surveys. Nonresponse issues need to be planned for at the beginning of the survey process, not reacted to at the end.
- There needs to be a clear recognition of the difference between sampling error (a function of the quantity of the data collected) and survey bias (a function of the quality of the data collected). In the past, too much attention has been focused on increasing sample size, which can increase the precision of the population estimates. However, not enough attention has been focused on removing biases, which increases the accuracy of the data.

Nonreporting is when a survey form, questionnaire, etc., is incomplete (Richardson, Ampt and Meyburg, 1996). Particular questions or parts of questions have been answered incorrectly or not at all. In a travel survey, examples of nonreporting are the nonreporting of trips and the characteristics of the trips. Reasons for nonreporting of trips are that the respondent has forgotten the trip, that the trip is considered unimportant or too short, or that the trip was performed on a mode not regarded as worth reporting (foot or bicycle) (Richardson, Ampt and Meyburg, 1996). Underreporting of trips is not limited to European

countries. According to Stopher *et al.* (2007), 7.4 percent of the trips conducted in the Sydney HTS were missed.

According to Saxton (2018a), some respondents find it hard to answer questions about where they have been. If they don't remember or know the address of a specific location they have been to, and the interviewer spends a lot of time trying to find it, it can lead to either a drain of concentration or the respondent chooses not to report all of their trips (ibid.).

2.9.2 Respondent Burden

Respondent burden is an issue in all survey research, hard to define, and affects quality. Elizabeth Ampt has done great work which provides insight into the respondent burden issue, and it is her understanding of the 'respondent burden' I use in this thesis. Ampt (2000, 2003) notes that the respondent burden is not a fixed unit, and respondents are diverse. She explains it as more of a perceived difficulty, intrusion, or dissonance that a person associates with a survey. Since it is perceived, the response burden varies within any population. It is, however, possible to reduce this perceived burden, and travel behavior researchers should try to identify what affects the perceived burden and address them if possible (Ampt, 2003).

Unfortunately, according to Ampt (2003), two external challenges affect the perceived burden of a travel survey: the increasing number of surveys in society in general and 2) some survey designers, especially those with inadequate knowledge of sampling and weighting, collect a large amount of complex data when they get the opportunity.

When designing a travel survey, we should aim to reduce the respondent burden as much as possible. Ampt (2000, 2003) recommends the following to do so:

- Finding the appropriate moment from the respondent's perspective: The respondent should influence the time and place to conduct the travel survey. The 'ideal time' varies depending on the respondent's life situation. A letter or e-mail is the least intrusive first contact.
- The researcher must show how the topic/theme of the survey is relevant/important to the respondent or their community because most people are more willing to do things they perceive as relevant/important. This can be done before data collection (invitation material), during (survey question formulation), and after data collection (media release about the results).
- Be careful of the respondent feeling external pressure to respond/not respond or respond a certain way.

- Keep it simple – is the survey perceived as complex physically (e.g., illiteracy in CAWI-TS or hearing impairment in CATI-TS), intellectually (most respondents do not understand technical terms like “mode,” “destination” or “rail,” some find computers difficult to use) or emotionally (the questions remind them of exams, fear of answering “wrong,” “big brother”-associations with computers), they might not participate even though they find the topic relevant/essential.
- Make sure the respondent is willing to give the specific information asked for
- The medium must be appropriate – respectful, easy to use, and understand
- Appeal to the respondent’s sense of altruism (for example, utilize people’s interest in pollution or traffic congestion).

According to Ampt (2003), the respondent has a threshold for each point before they consider participation and completion. Ampt (2003) stresses the importance of piloting and that the survey designers (e.g., the company or institution responsible for the NTS) should do some interviewing themselves, not just allocate the task. For self-completion surveys, it can be helpful to do participant observation studies and study non-verbal cues. Ampt (2003) argues that it is also increasingly important to diversify methods when collecting travel survey data.

Ortúzar and Lee-Gosselin (2003) used Ampt’s framework and definition of respondent burden to discuss issues and solutions further. They argue that respondent burden could lead to dropping out of a survey but also to intentionally uncooperative responses (spurious or obstructive behavior because the survey is too long or “nosy”) and unpremeditated errors (shortcuts in responses or hasty answers). Ortúzar and Lee-Gosselin (2003) argue that an all-around good survey design is the solution to these challenges. This can be done by finding a good balance between raising the tolerance of the respondents (e.g., proper use of incentives, clarifying legitimacy and importance of the study) while reducing the burden of participating (e.g., competent field staff, multi-mode solution, being sensitive with sensitive questions, limit the use of complex items, reducing the number of items in the questionnaire) (Ortúzar and Lee-Gosselin, 2003).

The respondent burden can affect the travel survey data; Madre *et al.* (2007) studied immobility in several travel diary surveys. They found that some respondents report immobile days to reduce respondent burden, i.e., saying that they were immobile not to report their travel behavior (i.e., soft refusal). According to Madre *et al.* (2007), identifying soft refusers (see Madre *et al.* (2007) for suggestions on how to identify them) increases the non-response rate, but it is worth it because it improves the quality of the estimators. Axhausen *et al.* (2007) studied fatigue in long-duration travel surveys and found that in

many shorter panel travel surveys, a loss of commitment to the task of participating was connected with a reduction in trips reported by the respondents. Trafikanalys studied which variables are challenging to answer for the respondent (Saxton, 2018a). According to Saxton (2018a), it can sometimes be difficult for the respondent to report their trips because they do not know the exact address of the place they visited. As a result, describing their start and/or stops can take a long time for the interviewer and/or respondent, which can drain the concentration of the respondent. This can lead to the respondent not reporting all of their daily trips (Saxton, 2018a). Trafikanalys also found that respondents have difficulty estimating the length of the trip.

2.9.3 Structures Affecting Data

It is important to remember how organizational administration can affect the quality of TS data. One example is the Victorian Activity and Travel Survey (VATS). Ampt, Ortúzar and Richardson (2009) discuss practical challenges regarding ongoing data collection, using the Victorian Activity and Travel Survey (VATS) as a case. VATS ran from 1994 to 2002. According to Ampt, Ortúzar and Richardson (2009), the quality of data in VATS declined after 2000 due to significant design changes made by market research companies with little experience running a large-scale travel survey. The changes were made to reach higher cost-effectiveness (Ampt, Ortúzar and Richardson, 2009). Furthermore, there was a loss of control in administration and documentation, and some of the data were never satisfactorily delivered to the clients. VATS was terminated after 2002, and to this day, most analyses focus on the data from before the design changes in 2000.

In 2007, VATS's successor, the Victorian Integrated Survey of Travel and Activity (VISTA) began data collection. The methodology was changed to overcome many problems identified in VATS. As of writing, VISTA still exists, although the method has changed somewhat since its inception, and it now has a GPS component (Victoria State Government, no date).

2.10 Minimizing Errors

In survey design methodology, quality is often understood as minimizing error[2] (Groves *et al.*, 2009). In paper II, I introduce the work of Dillman's Tailored Design[3]. According to Dillman *et al.* (2014), attention must be put to all aspects of the survey design to minimize errors. Furthermore, not one data collection method fits all situations, and sometimes a

[2] There are errors connected to the process after data collection is finished (i.e. processing error and adjustment error) (Groves *et al.*, 2009). Since these are not within the scope of the thesis, I do not discuss them here or in paper II.
[3] The principles of 'Total Design' were developed by Don Dillman in 1978, and later reworked and renamed "Tailored Design" (Richardson and Lawton, 2013).

combination of methods is best. The best method choice depends on the demographic composition, the topic of the survey, the geographic location, resources available, and sampling frames. A central idea of Tailored Design is that one should minimize Total Survey Error (TSE), which is the sum of (Dillman, Smyth, Jolene and Christian, 2014, p. 3): 1) coverage error (the sample doesn't represent the population), 2) sampling error (difference between the estimate produced by the sample surveyed and the estimate if every unit in the list participated in the survey), 3) non-response error (difference between the estimate if only some of the sampled units respond compared to if all of the sampled units responded), and 4) measurement error (difference between the estimate and true value due to inaccurate reporting). It is necessary to give attention to all four types of errors because if a method is introduced to reduce a kind of error, it could increase one or two of the other error types, thus increasing the overall TSE (Richardson and Lawton, 2013; Dillman, Smyth, Jolene and Christian, 2014).

2.11 Unit Nonresponse and Item Nonresponse

Traditionally, nonresponse has gotten the most attention in travel survey discussions. Frequently, one makes the distinction between unit nonresponse (UNR) and item nonresponse (INR) (Richardson and Meyburg, 2003). UNR refers to being unable to get information on a sampling unit (household or person). INR refers to having information about a sampling unit, but the information is incomplete. This is also the distinction I use in this thesis. However, there is a close connection between UNR and INR. Sometimes an observation with INR issues should be considered UNR. For example, according to Richardson and Meyburg (2003), in HTSs, sometimes some household members are missing. Thus, a challenge in HTSs is identifying when a responding household with some INR becomes a nonresponding household. Furthermore, according to Wilmot and Adler (2003), item nonresponse and unit nonresponse are closely connected because reluctant respondents are more likely to falsify, omit or misread information in a travel survey. Furthermore, these respondents are more likely to be unwilling to provide sensitive and/or personal information.

There are many definitions of item nonresponse, but what is common is that item non-response is an issue due to missing or incorrect data in a unit (Wilmot and Adler, 2003). Thus, item nonresponse is due to failure to obtain information for a question in an interview or questionnaire, resulting in missing data about a household or person. In the context of an ITS, this could be missing information on the respondent's trips within a day, a chain, or stage within a trip. According to Wolf *et al.* (2003), underreporting of trips is considered the worst because trip rates are the focus of TSs, and underreporting can cause severe problems in travel demand modeling.

Adler (2003) reviewed the literature on item non-response in travel surveys, i.e., the absence of some subset of data items in a survey. According to the author, the main non-response challenge in travel surveys is when respondents do not report trips or activities because it causes biased estimates of trip rates. According to Adler (2003), the most effective way to avoid item nonresponse is to prevent them from happening in the first place, both before and during the survey process.

2.11.1 How UNR and INR Affect the Quality

UNR causes a reduction in sample size and increases sampling error and costs (Kalfs and Evert, 2003). UNR is mainly a problem if the non-responders are systematically different (i.e., respond differently) to respondents because that indicates a biased sample (Wilmot and Adler, 2003). A biased sample can lead to over- or under-estimating variances (Kalfs and Evert, 2003). Furthermore, systematic differences could result in challenges with sample selection bias and results biased in unknown ways, challenging internal and external validity (Heckman, 1979; Berk, 1983; Winship and Mare, 1992; Cuddeback *et al.*, 2004). According to Wilmot and Adler (2003), item nonresponse can affect the quality of the data material of a travel survey in the following ways:

- It can result in the loss of an observation.
- If there is no or incorrect information on the location (for example, home address), it can render the observation “useless”.
- If item nonresponse values are misinterpreted by the analyst or a program.

The increase in nonresponse in TSs is most likely due to a combination of changing methods and an increasing reluctance from the public to participate in surveys in general (Stopher, 2009b). Suggested reasons for recruitment challenges in telephone interviews are increased telemarketing and increased reliance on mobile telephones, reducing the usefulness of traditional phone registers (Stopher, 2009b).

2.11.2 Reducing Item Nonresponse

Wilmot and Adler (2003) attempted to describe ways to reduce item nonresponse specifically (and unit nonresponse indirectly). They argue that the instrument design affects the item nonresponse the most. According to them, a questionnaire is an art form, and effort must be put into ensuring high quality (development, focus groups, pretests, pilot tests, etc.). The goal is to make it as user-friendly and respondent-oriented as possible (Wilmot and Adler, 2003). Furthermore, how the survey mode affects the item nonresponse depends on the chosen method: for example, traditionally, personal interviews result in lower item nonresponse because the interviewer can probe for information, and it is more difficult for the respondent to refuse to share information when there is a person there in

the room with them (Wilmot and Adler, 2003). One can build validity and consistency checks into the program/software in CATI or CAPI.

Furthermore, the interviewer can ask the respondent to clarify and sometimes even motivate the respondent to provide information that they initially withheld. The execution of the survey is also critical because it affects the motivation of the respondent (Wilmot and Adler, 2003). Execution includes conducting data collection at a time and place that works well for the respondent. The respondent is provided with necessary assistance and instructions to answer the questions, are reminded of participation, and know what to do if they have questions. Wilmot and Adler (2003) state that a good survey execution requires experienced survey management and well-trained field workers. Finally, some contextual (social, economic, cultural, etc.) factors can affect item nonresponse. This can, for example, be the public perception of the survey agency (good or bad) or budget and time constraints.

Although the best way to avoid nonresponse issues is to reduce them before and during data collection, there are ways to mediate them afterward. For example, inference and imputation can be used to treat INR (Wilmot and Adler, 2003).

2.11.3 Nonresponse in GPS and Smartphone Travel Surveys

There is limited research on whether non-respondents in a smartphone TS vary from non-responders in a traditional TS, although recruitment is challenging (Saxton, 2018b). However, some research has been done on TSs with GPS devices. According to Stopher's (2009a) review of research on this topic, results differ from TS to TS. Still, he concluded that the sociodemographics of a GPS sample would not be "markedly different" from those participating in a conventional TS. Bricka (2009) studied differences between GPS and traditional methodology non-responders using data from the 2004 Kansas City Regional Household Travel Survey and found that although the GPS method increases response rates among some groups, it exacerbates nonresponse among other groups. She suggested that techniques must be implemented to mitigate UNR among low-income, minority, and older people in a GPS TS. Bricka (2009) also studied INR and found it important that equipment size is easy to use, and that respondents must be reminded to keep the devices close to items they always bring (e.g., phones or keys). Although using a GPS device reduces the time it takes to report their trips, the battery life and portability of the device affect the respondent burden (Bricka, 2009). Non-response in GPS TS was discussed at one of the workshops of ISCTSC 2008 (Contrino, 2009). They found that although GPS devices have become a viable option for data collection, it is dependent on

human acceptance of the technology and their follow-through on using it (installation, battery replacement, downloads, charging, returning the device, etc.).

Wolf *et al.* (2003) compared the GPS-measured and CATI-measured trip rates and found that the GPS logger registered more trips than the CATI interviews did. However, some GPS trips were not captured, indicating that changing the method does not entirely fix nonresponse.

2.12 Guidelines, Tips, and Tricks Regarding Recruitment

Stopher *et al.* (2006) have made a comprehensive description of standards and guidelines on how to conduct a successful HTS. On a practical level, when it comes to recruitment and reducing non-response, Stopher *et al.* (2006) suggest the following:

- A minimum number of key questions is necessary, and much care must be taken in the wording of these
- Reminders are essential and should be used[4]
- Item-nonresponse can be minimized by good survey design (the best design varies depending on the data collection method)
- Unit-nonresponse can be minimized by using incentives, pre-notification letters and reminders, and increased recruitment efforts for hard-to-reach households (i.e., hard-to-reach groups)
- Shorter surveys should be chosen if possible
- Providing flexibility on when and how to respond can increase participation, although more research is needed
- Pilots and pretests are recommended
- The respondent burden should be reduced as much as possible

Ampt and Ortúzar (2004) reviewed best practices in continuous large-scale mobility surveys focusing on HTS. They point out how the survey instrument needs to minimize respondent burden. In a self-completion research design, it is necessary to know that the instrument is user-friendly, uses simple language, and is nicely presented. Further, they recommend conducting a pilot survey before collecting large-scale data. Ampt and Ortúzar (2004) present some results from the recruitment in the Santiago Mobility Survey. In the pilot stage, the survey forms were carefully designed, using attractive colors, and tested on focus groups. This led to a simplification of the design of recruitment material. In the first

[4] According to Ampt *et al.* (2009) reminders should not be relied on to increase response rates in ongoing surveys, because some respondents self-select the travel day to make participation easy (i.e. they report on a day with few trips).

wave of the final survey, Ampt and Ortúzar (2004) did an extensive marketing campaign, which was launched shortly before the start of the survey. The aim was to inform people of the survey. The marketing campaign included road and bus signs, newspapers, radio, and leaflets distributed to households, at malls, and events. The campaign continued throughout data collection, and a focus group connected to the survey suggested that the campaign was essential to the success of data collection (Ampt and Ortúzar, 2004).

2.12.1 New KONTIV Design (NKD)

Socialdata developed the New KONTIV Design (NKD) in Munich (Moritz and Brög, 1999) and has been used in multiple European countries, including Germany, Netherlands, and Austria (Ortúzar *et al.*, 2011). A premise of New KONTIV is that 'the researcher must adjust to the respondents, not the respondent to the researchers'. According to Brög (2015), the survey needs to be respondent-oriented, and the respondent should be treated as a partner, not an object. The response rates using this method have traditionally been high. In NKD, the respondent is asked as little as possible, the respondent gets to choose the survey instrument, there is a possibility for follow-up surveys for specific subgroups or if certain research topics arise, and there is a decentralization of organization (Moritz and Brög, 1999; Ortúzar *et al.*, 2011; Brög, 2015). The respondent mostly self-administer their trips, but interviewers are used to motivating participation.

2.12.2 Travel Surveys from a Planning Perspective

Richardson *et al.* (1995) wrote a book about survey methods in a transport planning setting and gave some practical advice relevant to the recruitment of respondents. On the issue of developing the questionnaire in a self-completion survey, it is essential that the questions included appear relevant to the respondent and that it is designed in a way that encourages participation from all types of respondents, no matter how knowledgeable they are in filling out a survey. For example, the researcher should provide a short, simple-worded (i.e., non-technical) description of the aim of the study, give general instructions on how to participate, and assure the confidentiality of data to the respondent.

Before data collection, it can be helpful to publicize the survey to increase the response rate, either to the general population or to the respondents in the sample directly (Richardson, Ampt and Meyburg, 1995). One can publicize the study to the general population by using public media, for example, running a community interest story. However, it is essential to not oversell the survey. A way to publicize the survey to the sample is to send a letter directly. This has two purposes: 1) to make the respondents aware that they will be contacted for the survey soon, thus making them less suspicious of further contact, and 2) it gives the respondent time to think about the subject matter. A

combination of general and direct pre-publicity resulted in increased trust of the interviewers amongst older people during a survey in Sherbrook Shire, Victoria, Australia (Richardson, Ampt and Meyburg, 1995, p. 233).

Richardson *et al.* (1995) argue that the most critical factors determining the response rate when conducting self-completion surveys include:

- Using reminders
- Having official survey sponsorship from a respected and well-known institution, group, or individual (research institutions, government authorities, universities, etc.). These mustn't be controversial
- Use special measures to ensure the participation of all groups
- The best incentive is a good survey design where the purpose is clear, the layout is easy to understand, and it is easy to contact someone with questions
- The cover letter is the first impression of the survey, so much care should be placed in developing this (not overly personal, but friendly)
- Having a service

Richardson *et al.* (1995) also highlight the importance of conducting pilots and/or pretests before collecting large-scale data to test the survey design and make improvements. Later, Richardson *et al.* (1996) added the following when presenting strategies to minimizing nonresponse:

- Having a comments section at the end of the questionnaire gives the respondent a way to share their views on the subject
- Using special postage (stamped return envelopes) in mail-back surveys
- Language assistance if there is data collection in an area where respondents speak different languages

2.13 Definitions

Paper I-III uses methodological theory, standards, and policy as a "theoretical framework" and basis for discussion. Papers I-III are also more focused on the meta-perspective of travel surveys and historical overviews. In contrast, in paper IV, I attempt to explain human behaviors using theories from sociology and psychology. In this subchapter, I briefly describe how I define quality in the thesis, and some key definitions used in paper IV. For a more detailed description of the theories from sociology and psychology, it is advised to read paper IV.

2.13.1 Quality

There is not one clear definition of quality in travel survey data, making it challenging to define. Quality is still essential in travel survey methodology, and entire conferences have been dedicated to the issue (the books based on proceedings from ISCTSC 2001 and 2004 are worth noting and reading for those interested in the subject). Thus, I decided to study quality from multiple angles/collect different measures[5] of it.

The first way is to study the response rate over time in the NTSs because it can affect UNR and INR and cause sample selection bias. Although it shouldn't be used as the only quality measure, it is probably the most used measure of quality in surveys. The second way is to study transportation-specific standards of quality, which are commonly used metrics to discuss the quality of travel survey data (Stopher and Jones, 2003; Stopher *et al.*, 2006). I study two:

- Share of immobiles: a high share of respondents reporting zero trips on the day of reporting is by many researchers (Stopher *et al.*, 2006; Madre, Axhausen and Brög, 2007), considered problematic and reflective of the quality of the survey technique because a high share of immobiles can indicate a high percentage of soft refusal
- Trip rate per person/household in a travel survey: trip item non-response, i.e., failing to obtain correct trip information from the respondents, is a commonly used metric to discuss quality (Brög *et al.*, 1982; Richardson, Ampt and Meyburg, 1996; Richardson and Meyburg, 2003; Wolf *et al.*, 2003)

The third measure of quality I study is representativity, focusing on the data's geographic and demographic representativity. Representativity issues in travel survey data usually stem from the sampling frame, non-response, and measurement errors (Armoogum, Ellison and Kalter, 2018).

Lastly, I look at the overall survey design choices and methodological approach, including transparency in methodology documentation and potential weaknesses. Since external factors, such as changes of critical people in the project (e.g., what happened in VATS), can affect data quality, the meta-data must be of high quality and accessible if there is a change of people working on the project, planning of survey design and/or data collection.

2.13.2 Risk

I use Ulrich Beck's (1992, 1999, 2009) definition of risk (anticipation of catastrophe) and manufactured uncertainties (publicly manufactured risks) in paper IV. I used Beck's

[5] The quality measures included here is not an exhaustive list of measures of quality, and they are not necessarily independent of each other.

theoretical framework because Beck's 'risk society' is helpful when analyzing conflicting reactions to new technology (Sørensen, 2018). It explains why some people find certain activities potentially dangerous while others do not due to perceived future dangers and how there might be a mismatch of perceived risk between laypeople, scientific experts, and authorities. This is useful when studying reactions to new technologies, and Beck's work has e.g., been used to study phishing (Okpa, Ajah and Igbe, 2020), autonomous vehicle malware (Vassallo and Manaugh, 2018) and youth media non-participation (Chu, 2020).

2.13.3 Diffusion of New Technology

I use Diffusion Theory (DT) to explain the adoption process of new digital technology in paper IV. I mainly base the analysis on the works of Everett M. Rogers (Rogers, 1995, 2002). DT is useful when studying the adoption of new technologies (Sriwannawit and Sandström, 2015; Kasilingam, 2020). The work of Rogers (Rogers, 1995, 2002) is fruitful in explaining how an innovation (in my case a smartphone app) goes from the production phase to acceptance by the public. It has e.g., been used to study smartphone use (Kim, Chun and Lee, 2014), mobile banking apps (Tran and Corner, 2016), smart home technologies (Vrain and Wilson, 2021), digital low-carbon innovations (Wilson, Andrews and Vrain, 2022) and chatbots (Kasilingam, 2020; Hari, Iyer and Sampat, 2022). DT explains the process of how an innovation (idea, product, etc.) is adopted by different groups at different stages and the distribution of people in each group (Rogers, 2002).

2.13.4 Privacy

On the theme of privacy, I ended up using literature from psychology. I chose the works of Rachels (1975) and Francis's (2008) interpretation of Rachels's theory because it explains why some people might be hesitant to share what some transport researchers might perceive as "mundane" information. To put it simply, to some, mundane information can be sensitive. As a travel behavior researcher, it is essential to understand why.

According to Rachels (1975), whether person A needs privacy on a particular issue or if they consider sharing information depends on the nature of the relationship with person B. Person A must have control of information and access to personal space if necessary. Furthermore, what is considered "sensitive information" is not universal from Rachels's perspective (Francis, 2008). For example, information such as age can be susceptible to some people and in specific contexts. To others, however, it may be regarded as trivial information. This can also be applied to the travel survey context. For example, what activities a person did on a particular day may be trivial information to some people, and they might not worry about sharing this information. To others, sharing such information with a stranger (i.e. researcher) may be considered sensitive or private.

2.14 Knowledge Gaps

NTS practitioners, transportation planners, and transport modelers meet a lot of practical challenges regarding data quality, either during the survey design phase (e.g., recruitment challenges, cost limitations, and increasing data demands) or they identify issues in the data material when they analyze it (e.g., UNR and/or INR). Low-quality data can lead to low-quality transportation planning and policy decisions; if the data does not reflect the travel behavior of the population it is meant to describe, it is not a sufficient basis for decision-making.

There are two main knowledge gaps that I have identified throughout the research process and aim to contribute to filling: 1) new models and methods demand high-quality data while the data quality is declining, and 2) smartphones are relatively new (time and novelty). The first knowledge gap is an overarching and perpetual methodological challenge. The second one is more practical and regards a current technological revolution we are experiencing in real-time. Below, I explain each one in more detail.

1) New models and methods demand high-quality data while the data quality is declining: Travel behavior researchers are paying less attention to the issues of data collection, survey design, and data quality even though the problems are increasing. At the same time, the models for forecasting travel behavior are becoming more advanced and complicated, demanding better data. As Ampt *et al.* (1985, p. 11) noted already in the conference summary of the second conference on Transport survey methods:

> The disparity between the sophistication of the transport models and the data used by them has already been noted. Since poor data can render even the most finely tuned model useless, this was a common over-dinner theme, and certainly the over-riding one in the Survey Needs for Modelling workshop.

And Richardson *et al.* (1996, p. 85) in the 1990s:

> Unfortunately, there are many examples in the literature of researchers concentrating their efforts on the more challenging exercise of developing sophisticated mathematical models without proper attention to the quality of the data that they use to validate these models. However, there is a trade-off between data quality and sophistication of the modeling process. Without a knowledge of the characteristics of the data set used, it is almost impossible to draw proper conclusions about the quality of such models, since the source of the problem could lie in the data base or the model itself.

Both quotes still hold in 2023. There has been a decline in interest in methodological development from a meta-perspective over the last 10-15 years. Thus, fewer papers are looking at the meta-perspective at NTSs in the past 1-2 decades. This can result in practitioners making the same mistakes in multiple countries, not sharing/documenting their experiences. The contrast regarding interest within the field is sharp. It shows that the

focus in transportation research has been primarily on model development, and data collection is mainly a derivative of said model development. As a result, methodology development in the data collection process has slowed since the mid-2000s. We are now facing a situation where we have a supply of data that does not hold up from a quality perspective in a world of models demanding high-precision and detailed data.

2) Smartphones are relatively new (time and novelty): We do not know much about the effect of smartphones in travel surveys regarding respondent reactions and who would participate/not participate in a smartphone app survey, simply because smartphones are relatively new. Furthermore, when smartphone app surveys are conducted, mode effects are not discussed much due to lacking resources or a different focus. Again, there is not yet an international consensus on what a smartphone travel survey is or how it should be conducted (there are no official or unofficial guidelines or practices). In some papers, a smartphone TS is simply defined as a survey on a smartphone; in others, it is passive only registration of movement. In the case of research using location data, some studies have the respondents validate their trips, while others crowdsource data from apps. The number of days varies a lot between studies (should it be one day or two weeks of data collection?). Some include a background questionnaire. Other studies collect background information from other sources.

The travel survey community has identified the potential of smartphone data but has not yet identified the full extent of the implications on data of changing data collection tools. Thus, we need to study this further. However, quite a few have speculated on their effects, and we could perhaps learn something from when CATI, CAWI, or GPS devices were considered “new technology”. After all, the traditional telephone was once considered “new.” Although smartphone tracking is not necessarily considered “new” anymore, for this thesis, when referencing “new technology” in a travel survey context, it is referencing using smartphones to track movement which is then used to study travel behavior.

Regarding these knowledge gaps, I attempt to do the following: 1) provide enough information to give practitioners a resource of the practice on travel survey methodology in selected European countries and 2) study respondent responses to smartphone technology to find out how changing the method could potentially affect the data.

3 Methodology

In this chapter, I present the overall methodological approach of the thesis. Then, I describe the studies and data material I have used as the basis for writing the papers and thesis: a document study, a quantitative analysis of NNTS data sets (2016-2019), an Enquête, four data collections using the smartphone app TravelVu, a focus group study and personal interviews. I have structured the presentation of data material based on how they were used in the papers and not chronologically. At the end of the chapter, I discuss potential limitations.

The main ambition of this thesis is to contribute to the methodological development in the field. Throughout the papers, contributions have been specified according to their specific context. In this chapter, I present the overall approach. Thus, parts of the following pages will reiterate insights delivered in the separate papers; I describe what I have done in the papers, but go more in-depth for specific areas of particular importance to the overall ambition.

This chapter explains both what I have done and why I have done it.

3.1 Research Strategy

I have chosen a pragmatic approach to this thesis, i.e., using the methodological approach that works best for the particular research question (Robson, 2002). This has led to using both qualitative and quantitative methods. Even though the papers are based on research theory, they are not theory-heavy. The main reason for choosing a pragmatic approach is limited research on smartphone technology in travel behavior research from a meta-perspective. The secondary reason is interdisciplinarity (see 3.1.3.).

Furthermore, ‘smartphones in travel surveys’ is still in development (technologically and policy-wise). More literature has come out at the end of my thesis work, but at the beginning of the project, academic literature on the subject was limited. Mostly, there was a discussion on the potential of smartphones and only a few studies on the *actual* effect of using the technology in a TS. Therefore, the pragmatic approach is obvious in paper I and II. In paper III, the research design is case studies. Paper IV is an interdisciplinary paper based on results from two qualitative studies. I use theories from sociology and psychology.

I have two central units of analysis that I have studied in the thesis: national travel surveys and the respondent.

3.1.1 Mixed-methods

Mixed-methods studies combine both qualitative and quantitative methods (Robson, 2002). I use mixed-methods in paper I and III. Using mixed-methods is natural when choosing a pragmatic approach. Considering “what works best?” depends on the research question, availability of information, and resources. The advantages of using mixed-methods are that it reduces inappropriate certainty and there is potential for methodological triangulation (Robson, 2002). The drawbacks of using various methods are that they are more time-consuming and can provide conflicting findings (Robson, 2002). I have not had an issue with contradictory results, but it has been time-consuming. Still, using mixed-methods has increased the quality of the analysis, so it was worth it. For example, in paper I, qualitative and quantitative methods revealed issues with the NNTS. A natural continuation of this was to look at the NNTS in an international context, resulting in paper II. Using both qualitative and quantitative methods in paper III provided insight into what challenges need to be dealt with in smartphone travel surveys. Thus, in paper IV, I attempted to better understand respondent behavior using qualitative analysis. This thesis would not have been possible with a purely qualitative or quantitative approach.

3.1.2 Case Studies

In connection with paper III, case studies were chosen as the appropriate approach, mainly because the experiences made underway were so valuable (Yin, 2014) and affected choices made in later data collections. Furthermore, it was fruitful to approach smartphone travel surveys from a case study approach because it was, at the beginning of the thesis work, a contemporary/novel phenomenon with limited published research that needed to be studied using multiple sources of evidence. Paper III was written based on multiple data collections and analyses of qualitative and quantitative data, typical of case studies (Robson, 2002).

3.1.3 Interdisciplinarity

Although transportation and travel surveys are interdisciplinary fields, it is dominated by engineers and economists and their theories. Psychological theories have become more popular in certain areas of travel behavior research. Sociology (my background) lags a bit behind in numbers (both in people and theories), although I have met other sociologists working with travel behavior research.

Social sciences are great resources for studying methodology and human behavior. Still, I decided to write a thesis at the Faculty of Engineering, meaning I must write a thesis which fits within the civil engineering field. There were some interdisciplinary challenges, which is part of the reason why I focus more on studying travel surveys from a meta-perspective:

Since I come from a different background than most of my colleagues, I spent some time exploring the discourse, unwritten rules, practices, and systems within travel behavior research to find “my place.” Furthermore, I ask some questions and make reflections that people from other academic backgrounds might not consider, simply because we have different educational experiences. This makes interdisciplinarity both challenging and valuable.

The main advantage of my sociology background has been the knowledge of methodology (quantitative and qualitative). I used sociological theory in paper IV because I believed I had found the right balance between the field of travel behavior research and sociology. Successful interdisciplinarity work demands a certain amount of knowledge of both fields. Otherwise, it is easy to fail in both camps simultaneously due to varying practices.

Still, looking back at the papers, the sociology has been present throughout the work (although not as explicit as in paper IV): In papers I and II, I discuss how the structures around the NTS affect the data quality, and in paper III I discuss how groups react to technology. Nevertheless, the thesis is written within the framework and according to practices established in the field of travel behavior research and the department I am employed at.

3.2 Document study

The pragmatic approach (Robson, 2002) to data collection was necessary to get enough information to thoroughly review the NNTS in paper I and compare countries in paper II. The reason for choosing a pragmatic approach was practical challenges (language barriers, not all information is open access, changing practices for reporting results).

Documents can be several things, but I mainly included official reports, journal articles, emails, statistics banks, and web pages. There are multiple ways to use documents in research. Prior (2011) describes different approaches to using documents. In this thesis, I mainly use them as a resource (gather information) and did a content analysis (Robson, 2002) in papers I and II when reporting survey design and transport-specific quality measures. To some extent, I also studied the documents as topics (studying how the content has taken the form it has) by studying how changing the structures around the NTS data collection affects the documents, but it is mainly a *meta-analysis*. A meta-analysis is “an analysis of the analysis” (Robson, 2002, p. 368), where one summarizes the results from multiple studies.

Documents are not neutral, and organizations represent themselves through their public documents (Atkinson and Coffey, 2011). The documents are ‘social facts,’ not transparent

representations of the organizational, professional practices, routines, or decision-making processes. Documents are written within a context, can have a purpose, and social, cultural, and institutional aspects can affect them (Robson, 2002). This is important to know when approaching them because we need to know what they are and what they aim to accomplish (Atkinson and Coffey, 2011). Robson (2002, p. 351) makes a distinction between witting evidence (what the author intended to impart) and unwitting evidence (everything else that can be gathered from the document). The documents analyzed in papers I and II were mainly used to disseminate results from NTSs and document methodology (witting evidence). However, as discussed in paper II, some transparency issues (unwitting evidence) existed.

Culture also affects the documents (Atkinson and Coffey, 2011), which can vary between organizations and countries. This is reflected in the documentation when data collectors change and how key numbers are reported between countries. Studying the culture of reporting travel behavior between countries and data collectors is a study of its own and not something I go deep into in this thesis beyond a discussion of transparency in paper II. However, what is included (and not included) in the documents says quite a bit about what the organizations and institutions focus on and how they wish to present themselves.

3.2.1 Data Collection

In document studies, one analyses documents made for purposes other than research (Tjora, 2021). The documents give information about a situation in a specific space and time. An advantage of using documents to review the NTS situation is that it is a non-intrusive way to review the situation. The data collection was done in two phases, which are based on what type of document was collected. The original plan was only to do “phase 1” (collecting official documents/government reports on NTS) because that is what we did for Norway. However, we could not collect all the necessary information in this phase, which is why we had to add new types of documents. Thus, “phase 2” (collecting documents written based on NTS data material) was necessary. The snowball method (Wohlin, 2014) was used during data collection in phases 1 and 2. The phases are described in more detail below.

Most documents were recipient designed, i.e., constructed with a specific reader in mind (Atkinson and Coffey, 2011). In phase 1, the documents are mainly written for people employed in transport agencies. In phase 2, the documents are aimed more at researchers. I collected information from the documents and created tables that present “timelines” of information. The tables with historical overviews in paper I and II are reworks of these tables.

3.2.1.1 Phase 1

This phase started at the beginning of the Ph.D. and continued to September 2022[6]. The process began with reviewing the methodology of the Norwegian NTS. For the evaluation of the Norwegian NTS, I did all of the data collection myself. The data collection of key reports has been done over the entire Ph.D. period because reports were published semi-regularly with new results. The main work of systematic analysis of the Norwegian NTS was done in December 2021 and January 2022. This resulted in a conference paper presented at the 12th international conference on travel survey methods (ISCTSC). This inspired/showed the necessity of making an international comparison. Thus, some results from Norway were reworked and became a part of paper II. I focused on the key reports, and connected documents discussing the NNTS methodology and quality. To limit the number of documents for non-Norwegian countries, the following selection criteria were used:

- Open access information on methodology
- Online documents
- Official descriptions of the national travel survey methodology

When comparing the NTSs in paper II, I decided to stop at 2019 due to COVID-19 potentially affecting transportation-specific quality measures. This is why there are 2020 results in paper I, but not in paper II. When comparing countries, I compare numbers assumed to be stable, given a stable society. If I included results from 2020-2022, the pandemic would have affected them. The data collection on other European NTSs began in February 2022.

The documents were collected using various methods, and they are written in multiple languages. Considering the number of documents to go through, time limitations, and language barriers, I got help from research assistants employed at the department for the international comparison. The research assistants each received a country and institution to collect documentation from and a guide with a list of what to look for. We had weekly meetings during data collection until their exam period started. From June-July 2022, one research assistant had a summer job at the department and did some of the late-stage data collection of this phase.

[6] The first round of data collection lasted until July 2022. Fall 2022, we got access to a document explaining the planning of the first NTS in Norway (Bolkesjø and Solheim, 1984). Thus, it was a late addition to the document study, but a valuable one.

Table 2 Resources in the document study data collection process

Country	Documentation web pages (where we started)	Resources during data collection
Norway	Norwegian Public Roads Administration (vegvesen.no) Institute of Transport Economics (toi.no)	None
Sweden	Trafikanalys (trafa.se)	Research assistant (phase 1)
Denmark	Center for Transport Analytics, Transport DTU (cta.man.dtu.dk)	Research assistant (phase 1)
France	Institut national de la statistique et des études économiques	Research assistant (phase 1 and 2)
England	Department for Transport (gov.uk)	Research assistant (phases 1 and 2)
Germany	Federal Ministry for Digital and Transport (Bundesministerium für Verkehr und Infrastruktur (BMVI)) (bmvi.de/EN) German Aerospace Center (DLR)[7]	Research assistant (phases 1 and 2)

The process was as follows: we started with collecting methodology documentation of the newest NTS of the respective country and then worked backward in time. The following information was sought out:

- Trip definition
- Average trip production/frequency per unit of analysis per day
- Survey design
- Sampling method
- Response rate
- Comments on possible bias and inference

Data was collected for Sweden, Denmark, France, England, and Germany. However, the data from phase 1 was insufficient to get a good enough picture of all of the NTSs due to language barriers or transparency issues. For example, in France, most of the official documentation was in the native language. Fortunately, one research assistant read French, which helped the process a lot. Still, this was insufficient to get a good enough picture of the non-Norwegian NTSs. Thus, it was deemed necessary to widen the types of documents studied.

3.2.1.2 Phase 2

This phase is considered to be March-July 2022 and does not include Norway. To find a more detailed description of the methodology of NTSs, I had document searches of peer-reviewed conference papers and journal articles using the data from relevant NTSs. I

[7] One of the reason for using DLR as a source was that they had multiple documents listed and had English descriptions of KONTIV and MiD.

started with procedia from the International Travel Survey Conference (ISCTSC) for this. Google Scholar was also used as a search engine. Finally, I searched for the English name for the respective travel survey. Thus, papers describing the methodology of the following travel surveys:

- German Mobility Panel (MOP)
- Mobility in Germany (MiD)
- French National Household Travel Survey

In the end, I excluded the results from the German Mobility Panel (MOP) from paper II because the methodology differs from the NNTS. However, it is still relevant to the theme of this thesis, and I thus included some of the results from this data collection in the background chapter, and in Appendix F.

In paper II, I did not include data collection for all years in the tables for each country. For Norway, I have included all years included in paper I except 2020. For Sweden, I included 2005-2019 because the survey design has changed so much after the NTS was "relaunched" in 2019, and there is limited information on the elder NTSs. For Denmark, I mainly include information on the latest (third) generation, although a summary of the previous generations is included. A DTU employee provided some key information by e-mail to finalize the table. For England, which has data collection every year, I removed some years that did not have significant changes to keep the table within a reasonable size. I included all data collections for France because they have not conducted that many NTSs compared to the other countries. For Germany, I only included information on MiD (2002, 2008, 2017) and not KONTIV (1981, 1989) because 2002 was the first study in reunified Germany (Federal Ministry for Digital and Transport, 2020).

3.2.2 Transportation-specific Measures of Quality

When estimating the trip rate in paper I and immobility in paper II, the change in weighting practices and analysis choices resulted in varying numbers in the documents. Although the 'true value' of trips is perhaps stable, assuming stability in average trip rates in public documents is problematic at best. On the international level, varying definitions (for example, some countries have distance requirements) and sampling frames make comparisons challenging. On the national level, trip estimates change due to changing weighting practices and survey design choices over time. Some changes, such as changing weighting practices, can be mediated if you have the original data sets available. Others, such as varying methodological choices and definitions, have less apparent solutions (if any).

When studying the trip frequency and share of 0 trip days in Norway, I found that the trip rate for a specific year sometimes changed in the key reports as time went on. This was mainly due to the evolving practices in weighting (the NNTSs did not use weights in the beginning), but perhaps also due to varying analysis choices and methods (some respondents might be included or excluded from analysis, without reason being documented in the key reports). Thus, the trip rates included in papers I and II was the newest up until 2020 (paper I) and 2018/19 (paper II). This was important for comparison reasons. All of the trip rates collected from the documents, both original and changed, are presented in Table 3.

Table 3 Average trip rate in the original document and change 1984-2020

	1984/85	1991/92	1997/98	2001	2005	2009	2013/14	2018/19	2020
Original	3.2 (Stangeby, 1987)	3.15 (Vibe, 1993)	3.2 (Stangeby, Haukeland and Skogli, 1999)	3.09 (Denstadli and Hjorthol, 2002)	3.33 (Denstadli *et al.*, 2006)	3.3 (Vågane, Brechan and Hjorthol, 2011)	3.26 (Hjorthol, Engebretsen and Uteng, 2014)	2.82 (Grue, Landa-Mata and Flotve, 2021)	2.35 (Opinion AS, 2021)
Update 1		3.26 (Stangeby, Haukeland and Skogli, 1999)	3.14 (Denstadli and Hjorthol, 2002)	3.03 (Vågane, Brechan and Hjorthol, 2011)			3.22 (Grue, Landa-Mata and Flotve, 2021)		
Update 2		3.12 (Denstadli and Hjorthol, 2002)							

For the share of 0 trip days (share of immobile), I only did this for 1984-2019 because we did not include documents after COVID-19 hit in paper II. Furthermore, this number has only changed for one year, 1991/1992 (see Table 4).

Table 4 Share of respondents with 0 trips on the day of reporting 1984-2019

	1984/85	1991/92	1997/98	2001	2005	2009	2013/14	2018/19
Original	17 % (Stangeby, 1987)	13.80 % (Vibe, 1993)	11 % (Stangeby, Haukeland and Skogli, 1999)	15 % (Denstadli and Hjorthol, 2002)	12 % (Denstadli *et al.*, 2006)	14 % (Vågane, Brechan and Hjorthol, 2011)	10 % (Hjorthol, Engebretsen and Uteng, 2014)	14 % (Grue, Landa-Mata and Flotve, 2021)
Update 1		12 % (Stangeby, Haukeland and Skogli, 1999)						

The changing trip rates and share of immobiles are essential for understanding that it is necessary to read a document within the context of the time it was written. Furthermore, it illustrates how the change in methodology has changed practices of estimating the "stable numbers" of transportation, making them not very stable. When studying Norway in the international context in paper II, we have aimed to find the newest numbers available. Nevertheless, practices of estimating and weighing these metrics change over time and between institutions, meaning these numbers may vary depending on the documents chosen. This is also why I wanted to focus on official statistics from the data collector, quality controller, or authorized governmental branch responsible for the respective NTS as a first step.

3.3 Norwegian National Travel Survey Data 2016-2019

I analyze data from the 2016-2019 NNTS in the paper I. There, I present some descriptive statistics of the NNTS samples and estimates on the trip frequency and share of respondents with 0 trips on the reporting day (i.e., immobiles in paper II).

3.3.1 Data sets

The Norwegian Public Roads Administration (NPRA) made the data sets available for analysis. We received data sets that included weights, and the sample consisted of regional supplementary samples and a national sample. The data sets are not the same as those used in the key reports by Grue *et al.* (2021). The data set in the key report for 2018/2019 is a combination of information for two years, structured like one year, the argument being that this makes the data representative for 1 year (Grue, Landa-Mata and Flotve, 2021).

3.3.2 Descriptive Statistics and Statistical Tests

Grue *et al.* (2021) created their weights for estimations and compared years using their own data set structure. I did not have access to their data set or a sufficient description of how they constructed it to reconstruct their 2018/2019 data set. Thus, I believe it would be problematic to estimate travel behavior metrics and compare those with numbers from the key reports directly. Furthermore, paper I was mainly based on the document study. Thus, I focused on descriptive statistics on the sample composition based on the person files to say something about the representativity of the original data. Most of the estimates were unweighted since this was mainly an evaluation of representativity without a reference population. In paper I, I did statistical tests to test whether the differences between groups were statistically significant (Tables 2-4 in paper I). The detailed results from these tests are presented in this chapter (Tables 6, 7, and 9). I used Stata MP to do the analysis.

In the data set, there was a sample weight constructed based on gender, age, geography, and day of reporting, which I used to analyze travel behavior for 2019. Still, I mainly discuss unweighted results in paper I. Table 5 describes the samples.

Table 5 Sample description - interviews (2016-2019), N

	2016		2017		2018		2019	
	All	**NS**	**All**	**NS**	**All**	**NS**	**All**	**NS**
CATI	1646	1646	6839	1444	22100	1268	26820	1342
CAWI	1603	1603	7037	1254	17726	1064	22257	1132
Total (N)	3249	3249	13876	2698	39826	2332	49077	2474

All = national sample + add-ons, NS = National sample

Table 6 shows the results from two sample t-tests conducted to see if the CATI and CAWI samples have significantly different trip rates. The t-test is valid when studying means (Ringdal, 2018) which trip rates are. The variables used are daily trips by survey mode (CATI or CAWI). The t-tests show a significant difference between CATI and CAWI ($p<0.05$ for all samples and years, and t-values outside the interval +/-1.96).

Table 6 Two-sample t-test, unequal variances (variables daily trip rates by survey mode)

	All (national sample + add-ons)						**National sample**					
Year	**CATI**		**CAWI**		**t-test**		**CATI**		**CAWI**		**t-test**	
	Trips	**SE**	**Trips**	**SE**	**t**	**p**	**Trips**	**SE**	**Trips**	**SE**	**t**	**p**
2016	2.62	.05	2.93	.05	-4.549	.000	2.62	.05	2.93	.05	-4.549	.000
2017	2.73	.02	3.09	.02	-10.395	.000	2.64	.05	3.00	.06	-4.716	.000
2018	2.78	.01	3.07	.02	-14.113	.000	2.65	.05	2.95	.06	-3.629	.000
2019	2.69	.01	3.00	.01	-16.557	.000	2.70	.05	3.07	.06	-4.527	.000

I also conducted Pearson's chi-square test for the share of immobiles[8] by administration mode[9]. A chi-square test is often used to see if there is a relationship between two categorical variables and the natural choice if one is interested in testing whether there is a correlation between two variables in a population based on a cross table from the sample (Ringdal, 2018). I chose to do a chi-square test because the variables in question (share of immobiles and administration mode), are categorical and only had two values. Thus, a chi-square test was deemed the most appropriate to test statistical significance. The results from the tests are presented in Table 7.

[8] A recode of number of trips for reporting day. Variable construction: value 1=0 trips on the day of reporting, value 0=at least one trip on day of reporting

[9] A variable already included in the NNTS data sets with two values; CATI (1) or CAWI (2)

Table 7 Pearson's chi-square testing of share of immobiles in the NNTS (%) between CATI and CAWI samples

	All (national sample + add-ons)					National sample				
Year	**CATI**	**CAWI**	**Chi2-test**			**CATI**	**CAWI**	**Chi2-test**		
	%	**%**	**Chi2**	**df**	**p**	**%**	**%**	**Chi2**	**df**	**p**
2016	19.2	11.0	41.973	1	.000	19.2	11.0	41.973	1	.000
2017	16.8	9.3	137.480	1	.000	17.8	10.3	30.881	1	.000
2018	14.4	11.1	92.130	1	.000	15.3	12.1	4.890	1	.027
2019	15.9	11.2	230.588	1	.000	15.5	10.7	12.323	1	.000

The results indicate a statistically significant relationship between immobile respondents and administration mode for all years when we look at the entire sample and the national sample. The p-values are all below 0.05, and the chi-square results are above the critical value of 3.84.

3.3.3 Using Population data from Statistics Norway's database

In paper I, I compare sample statistics from the NNTS 2016-2019 data sets with data collected from Statistics Norway's database (Statistics Norway, no date a) to discuss representativity. I chose to use Statistics Norway's database because they have a large open-access statistics bank on register data on the Norwegian population. It is probably the closest to the "true value" or "ground truth" on Norwegian public statistics distributions. The income data is estimated by linking multiple registers and the highest level of completed education based on register data on education. Income and biographical data in SSB's database are collected using the following sources (Statistics Norway, no date b):

- Data from tax returns (wages and salaries, self-employment income, pensions, etc.)
- The Tax Register (taxes)
- The a-ordning (unemployment benefit, various tax-free transfers)
- Norwegian Labour and Welfare Administration (family allowances, basic and additional amounts, cash benefits, etc.)
- KOSTRA (social assistance)
- State Educational Loan Fund (loans to students, scholarships)
- Education statistics and household statistics from Statistics Norway (highest level of completed education etc.)
- Sample survey in the period 1986-2004. From 2004 totally census-based.

When discussing representativity, I considered studying both income and education. When estimating the distribution of income and the highest level of completed education, respondents who answered "don't know" or "do not wish to enclose" were coded as "missing" in the NNTS data sets. A high share of respondents was categorized as missing

for the income variable. I thus decided not to include the results from the income analysis in paper I and focused on the level of education. I only analyzed NNTS respondents 16 years and older because the data from SSB only includes people 16 years and older. The NNTS sample sizes are presented in Table 8.

Table 8 Sample size "highest level of completed education" and # missing, 16 years and older, entire sample and national sample 2016-2019, N

	All (national sample + add-ons)	**Missing**	**National sample**	**Missing**
2016	3079	65	3079	65
2017	12988	352	2556	82
2018	37784	779	2239	41
2019	45858	937	2303	49

After recoding the education variable to make it comparable with SSB distributions and estimating the values, I did chi-square goodness of fit [10]tests (Table 9) for the level of education for the entire sample, the national sample, and for men and women (total sample and national sample), with the SSB distributions as the hypothesized distributions, to test whether the NNTS level of education distributions were significantly different from the SSB distributions.

[10] Level of education is a categorical variable without at normal distribution, and in the goodness of fit test, one can test whether the observed and hypothesized distributions are significantly different. The distributions are from Table 4 in paper I.

Table 9 Chi-square goodness of fit tests on education level, NNTS distributions and SSB distributions, percent (age>=16)

Year	2016			2017			2018			2019		
	All	**NS**	**SSB**	**All**	**NS**	**SSB**	**All**	**NS**	**SSB**	**All**	**NS**	**SSB**
Men												
Basic school level	8.6	8.6	26.9	8.4	7.2	26.7	8.8	9.8	26.4	9.7	10.0	26.0
Upper sec. edu[11]	42.0	42.0	43.9	36.3	40.4	43.7	37.5	39.7	43.5	40.2	42.2	43.6
Higher edu. (short)	27.8	27.8	19.0	30.1	29.5	19.2	29.3	29.1	19.5	28.3	27.8	19.6
Higher edu. (long)	21.7	21.7	10.2	25.2	22.9	10.4	24.3	21.4	10.6	21.8	19.9	10.7
Chi2	460.41	460.41		2651.62	437.45		6611.61	292.86		5970.54	246.49	
p-value	.000	.000		.000	.000		.000	.000		.000	.000	
Df	3	3		3	3		3	3		3	3	
Women												
Basic school level	8.8	8.8	26.2	9.4	9.2	25.7	8.9	11.0	25.2	10.3	9.6	24.6
Upper sec. edu [12]	35.8	35.8	37.3	34.4	33.9	36.9	33.1	32.2	36.6	33.3	33.1	36.3
Higher edu. (short)	35.2	35.2	27.8	33.2	34.0	28.3	34.3	34.8	28.7	33.6	34.3	29.1
Higher edu. (long)	20.2	20.2	8.7	23.0	22.9	9.1	23.7	21.9	9.5	22.8	23.0	9.9
Chi2	435.15	435.15		2120.16	429.34		6302.02	294.07		5948.96	317.76	
p-value	.000	.000		.000	.000		.000	.000		.000	.000	
df	3	3		3	3		3	3		3	3	

All = national sample + add-ons, NS = national sample

As one can see from Table 9, the NNTS distributions are significantly different from the hypothesized SSB distributions. For a more detailed description of the difference in distributions, see paper I.

3.3.4 Travel Behavior Estimates

In paper I, I did some estimations on travel behavior to see if the mode-effect suspicions of Grue *et al.* (2021) were right. Even though I did not have weights and data set structure used in the key report, I did have data for the same years. Thus, I studied whether or not I could find differences between CAWI and CATI respondents. I only included weighted results for 2019 because the provided sample weights for 2016-2018 were insufficient[13],

[11] Including tertiary vocational education
[12] Including tertiary vocational education
[13] When creating frequency tables, the N for weighted and unweighted results was different. Furthermore, multiple respondents had very high/low sample weight values.

and it would be wrong to use them without more information on how they were constructed. Unfortunately, when writing the paper, we did not have the codebook. Thus, we only included unweighted results for those years. The minimum and maximum values for 2019 were also a bit concerning but not at the same level as the other years. I suspect at least part of the reason for some respondents having extreme weight values is the geographical bias of the sample due to regional add-ons. Representativity challenges due to add-ons and weighting issues are discussed further in the Discussion (Chapter 5.3.1).

3.3.5 Reliability and Validity

Reliability regards whether repeated data collections with the same instrument give the same result (Ringdal, 2018). Reliability is weakened if the respondent misunderstands a question or remembers wrong. There are mainly three ways of evaluating reliability (Ringdal, 2018): source criticism, test-retest-reliability, and measuring the internal consistency (usually Chronbachs Alpha). I am mainly concerned with construct validity (Groves *et al.*, 2009). Validity concerns the relationship between the theoretical measurement and the indicators. In this thesis, I use validity in the context of whether or not we measure the theoretical concept we want to measure (Ringdal, 2018). There is a narrow and broad definition of validity (Skog, 2004), and I focus on the narrow one. The narrow one regards whether you have operationalized what you want to measure reliably and adequately. In the context of travel surveys, this can be the definition of a trip.

There are two concerns regarding reliability and validity and the NNTS. First is the issue of unit nonresponse, reflected in the low response rate, which can cause some challenges. Second is the issue of item nonresponse with potential underreporting of trips, but also how CAWI and CATI respondents might understand the trip definition differently. This could have affected the trip estimation and share of 0 trip respondents. Nevertheless, the papers focus on evaluating the data, not reporting travel behavior. Thus, even though validity and reliability are potentially challenged in the data, it does not pose a problem in the context of the analysis and the papers from a meta-perspective.

Reliability for the data sets included is not problematic when it comes to methodology (the CAWI/CATI solution was implemented in 2016). Still, the changing methods could provide some challenges when comparing if more years were included, especially in 2020, considering the change in data collector and temporarily going back to only CATI. Furthermore, for 2016, data collection was done only in the fall. Thus, comparability for this year is perhaps challenging for unweighted results due to seasonal variation.

3.4 Enquête

In the fall of 2017, a short “meta-survey” was carried out in Trondheim. The background for this survey was to get an indication of people’s preferences regarding using a smartphone app or traditional methods in a travel survey. The respondents were presented with two scenarios (Table 10).

Table 10 Scenarios presented in Enquête

Scenario A	Scenario B
Participate in a 20-minute interview about one day of travel behavior	Use a mobile phone app that passively registers trips for 7 days and 2 minutes per day to correct trips

In total, 259 completed the survey, whereas 246 responded to the survey in person, and 13 people responded online. The average response time was approximately 2 minutes. The sample is relatively small; young adults were overrepresented and recruited using convenience sampling. Thus, the results from this study cannot be generalized beyond those studied. However, getting an early indication of preferences and talking to people about the survey methodology was interesting. Furthermore, it proved quite easy to get people to participate in this meta-survey since it was so short.

3.5 Smartphone app Travel Surveys

There are many apps developed to collect travel survey data, e.g., ATLAS II (Safi *et al.*, 2015), MoveSmarter (Geurs *et al.*, 2015) or MEILI (Prelipcean, Susilo and Gidófalvi, 2017). We used the TravelVu app in all the pilots and data collections with a smartphone app. The main reason for choosing an existing app during data collection was that we realized early on that developing our app would be extraordinarily resource-demanding and not within the scope of the Ph.D. Furthermore, many apps were already in development at the beginning of the project. Thus, we chose to use someone else’s app. The app's requirements were to follow Norwegian and GDPR rules and regulations (the legal aspect is described and discussed in section 3.5.7), be developed to collect travel survey data, and be within our price range.

TravelVu was developed by Trivector and was made to study travel behavior. TravelVu collects information about the number of trips, trip length, distance, duration, geographic position, and purpose of a trip (activity) using GPS, accelerometer, and wifi/mobile phone data. The user then reviews the trips, corrects, and/or verifies them. Thus, the smartphone automatically detects and collects information about movement, starts, and stops, but the respondents must validate their trips during data collection. The respondents also have to report the purposes of their travels. Finally, the respondents are asked to provide some

background information by answering a short background survey programmed into TravelVu.

I have been a part of technical testing of TravelVu, and four more extensive data collections using TravelVu. I have named them Student Pilot, Trondheim I (spring), Trondheim II (fall), and Innherred (fall). The Student pilot was conducted in 2018, and the others in 2019. As mentioned in paper III, experiences from one study affected future data collection. Here, I explain how each study was conducted in chronological order.

3.5.1 Technical Testing of TravelVu

After researching potential apps and deciding that TravelVu would be a good candidate, a technical test was conducted. It was conducted in 2017, with the primary purpose of testing the technical abilities of the app, but also to see how user-friendly it was. The study was done in cooperation between NTNU, the Norwegian Public Roads Administration (NPRA), and Trivector. 33 people installed TravelVU, used it for 14 days, and then gave feedback on usability. The main conclusion from the testing was that it was good enough to test at a larger scale. The more detailed results can be found in the 2017 SmartRVU report (Svaboe and Tørset, 2017).

3.5.2 Student Pilot

For economic and practical reasons, the sample frame for the first pilot with TravelVu was students in Trondheim. The data collection was done in early 2018 (winter). Before data collection, the following was done: develop a questionnaire, develop an invitation letter, create an official e-mail, create installation and use guides, plan recruitment, and book stands.

The students were asked to use TravelVu for seven days. An economic incentive (a lottery of two gift cards worth 1000 NOK) was used. 242 people expressed interest in the study by signing up and receiving information, 199 downloaded TravelVu, and 171 registered trips for at least one day. The respondents were between 19 and 32 years, with an average age of 23. A sample description of the student pilot is presented in Table 11.

Table 11 Sample description (Student pilot)

Men		Women		Other/do not wish to answer		Total	
N	**Percent**	**N**	**Percent**	**N**	**Percent**	**N**	**Percent**
74	43 %	95	56 %	2	1 %	171	100 %

3.5.2.1 Creating e-mail

An *official e-mail* with both "ntnu" and "smartrvu" in the name was made (smartrvu@ibm.ntnu.no) for image purposes and practical reasons. That way, all mail activity could be between an official mail and not a specific person in the project group. Although I was the only Ph.D. candidate at the beginning SmartRVU project, this mail has been frequently used in most later data collections connected to the SmartRVU project. It has thus been a valuable long-term resource to the project group.

3.5.2.2 Planning and completing recruitment

We used multiple ways of recruitment in this pilot. Information about the study was shared using the following tools:

- Blackboard (the digital learning platform at NTNU)
- Innsida (NTNU's intraweb)
- Social media: asking friends and acquaintances to share information about the study
- Stands at campus with free coffee, biscuits, and chocolate
- Flyers and pamphlets
- Posters

If someone was interested in participating, they could sign up for participation. Before data collection, all participants received an information letter, which included information about the purpose of the study, how the data would be stored, anonymized, and who would have access. The information letter also informed all participants about how they consented to participate by downloading and using TravelVu. They were informed that all participation was voluntary and that they could withdraw their consent without giving a reason.

For the student pilot, YouTube videos described how TravelVu could be installed and used.

3.5.2.3 Questionnaire

Based on feedback from the focus groups (FG) (see 3.6), we wanted only to include relevant questions. One complaint in the FG regarding surveys was that questions were often considered irrelevant to their situation. The questionnaire (see Appendix A.1.) was specifically designed to fit students. We included minimum necessary background questions (e.g., age, gender).

3.5.3 Activities Before Data Collection, 2019

The student pilot provided some valuable experiences and showed that some preparations had to be made to increase participation and make data collection go as well as possible. Furthermore, a new bus system was implemented during the summer of 2019. Thus, we

wanted two data collections in 2019: one in the spring (before implementation) and one in the fall (after implementation). The fall data collection was also done in conjunction with the Travelviewer project. Trøndelag municipality was responsible for the Innherred data collection, although SmartRVU was a part of the project group. The survey design of Innherred was almost identical to Trondheim II. The main differences were 1) different populations and 2) some invitation letters were sent digitally in Innherred.

3.5.3.1 Creating Website

An *official website* for the SmartRVU project where one could find information about the study was created before Trondheim I. The URL for this web page is www.ntnu.no/smartrvu, and I got help from Mimir's well to make the first version of it. This web page has changed quite a bit since its inception, both in design and purpose. After more Ph.D. students started to work on the SmartRVU project, more people got involved, and it has been used in other data collections and projects. In 2022, the web page got a complete overhaul and now works to publicize work done in conjunction with SmartRVU and connected projects. Here, I focus on how it was in 2019 (when I created and oversaw it).

The website was linked to NTNU, and one goal of creating such a page was to increase the legitimacy of the studies by connecting the data collection to a recognized name and institution. If a respondent was curious about the project but uncertain about its legitimacy, the idea was that a quick Google search would send them to an official NTNU web page. The web page included information about the studies, practical information regarding TravelVu, whom we cooperated with, the project group's areas of interest, and contact information.

3.5.3.2 Logo

A SmartRVU logo (Figure 3) was made and included on all recruitment material and added to the web page header. The logo was created by me and my supervisor, Trude Tørset. The purpose of creating the logo was to improve the project's legitimacy and increase trust in us as data collectors. Furthermore, the SmartRVU project has grown quite a bit since its inception. As a result, this logo has been used on other materials since. I also included the logos of the partners in the invitation material (invitation letter, flyers, etc.)

Figure 3 Logo

3.5.3.3 Guides

A download guide and installation guide were posted on both the project web page and the app developer home page. Contact information for IT support can be found in the app and on the TravelVu homepage. Also, the respondent/participant could e-mail the official project group directly. The guides were tweaked for each data collection, and all project group members helped develop them.

3.5.3.4 Translations

TravelVu was developed in Sweden, and it was thus necessary to translate the app into Norwegian (there was already an English version). The translations started in 2017/2018 and were done continuously together with new updates up until the end of 2019. The TravelVu home page (https://www.travelvu.app/no) was also translated into Norwegian.

Due to the Travelviewer project, the app was translated into more languages. In Trondheim II, the respondents could use the app in either Swedish, Danish, Norwegian, English, German, Italian, or French. The background questionnaire was only in Norwegian and English. Trivector programmed the translations into TravelVu.

3.5.3.5 Questionnaire

It was necessary to include a questionnaire in TravelVu to get some background information on the respondent. The goal was to evaluate the app solution as an alternative or supplement to the current NNTS data collection tools. Thus, when developing the questionnaire, we used the questionnaire for the NNTS for 2018 as a basis. This was acquired from a contact in the Rail Directorate since the results had not yet been published. We then systematically tried to “strip it down” as much as possible because a) we wanted to stay close to the NTS data, b) we knew the current NTS questionnaire was too long, and c) it had to be adapted to a smartphone solution. The following rules were set during the cutting process:

- Remove questions that the app automatically registers or is defined in the app through alternative methods
- Remove all questions that theoretically could be collected through alternative registers (such as car models)

- Remove all questions regarding long trips

This resulted in the Trondheim I questionnaire (Appendix A.2), which included a maximum of 21 questions, depending on the respondent's answer. It had built-in skips and branching. Trivector programmed the questionnaire into TravelVu. The questionnaire was almost the same for Trondheim II (Appendix A.3 and A.4) and Innherred (Appendix A.5). The main differences were the introduction text which varied a little due to dates of data collection and geographical differences. In Trondheim II and Innherred, we included a question for how the respondent was recruited (in Trondheim I, the respondent participated in different surveys depending on the recruitment method) and removed one question about income. The reason for changing the questionnaire between Trondheim I and II was to a) improve the questionnaire and b) have the same questions in all the Travelviewer pilots.

3.5.3.6 Sampling

We aimed to have a similar sample to the NNTS national sample. Thus, we decided to sample from the National Population Register (Folkeregisteret/NPR), and at the time, the NNTS sampled from the NPR (Hjorthol, Engebretsen, and Uteng, 2014). The NPR has information on everyone currently residing or previously residing in Norway. When we contacted the NPR regarding sampling, we got the option to sample amongst people with a registered mobile phone number. Although this eliminated some potential respondents, we decided to use this register because it allowed us to send SMS reminders. Furthermore, we were about to recruit to a smartphone app TS, and it was more probable that those with a registered cell phone number owned a smartphone.

We deviated from the NNTS because we decided to have a different lower and upper age limit. We got a list of persons aged 18-70 living in Trondheim with a registered phone number. We decided not to include minors in our study because we were using tracking technology, and there were privacy concerns regarding children and tracking. Furthermore, we were not specifically interested in children's travel behavior. Thus, we decided that including minors was not worth the extra paperwork and potentially delayed data collection (we needed to begin data collection before the bus system changed). We decided to have an upper age limit because the penetration rate of smartphones is lower among elders. We also suspected that the eldest part of the population was less proficient in app use. In Trondheim I, we sampled 2000 persons, but due to the low response rate, we decided to increase the sample in the second data collection to 10 000 persons in Trondheim II and advised TFK to have a larger sample in Innherred, which they did. In Innherred, 12 450 persons (aged 18-70) with a registered address in Frosta, Levanger, Verdal, Inderøy, Steinskjer, Verran, and Snåsa were drawn.

3.5.4 Activities During Data Collection in 2019

3.5.4.1 Filed Notes

Field notes were taken during the data collection process to remember how the recruitment work went. They included information about what happened on what day, the current status of recruitment, and personal reflections. This was very helpful when establishing a timeline and reviewing the process after data collection.

3.5.4.2 Local Newspapers

We tried to utilize local newspapers in different ways. In Trondheim, I, the effect of advertisement was tested by buying an ad in the local newspaper's, Adresseavisen digital version. 50 000 'views' about the study were shown on the mobile version of Adresseavisen in the period 27.05.2019 – 02.06.2019 (see Appendix E.3). If the person clicked on the advertisement, they would get redirected to the project web page and read more about the study, and if they wanted to participate, download TravelVu. Since this was an expensive and inefficient recruitment method, we did not do this in Trondheim II.

Local newspapers wrote articles during data collection of Trondheim II and Innherred. *Adresseavisen* wrote one article about Trondheim II. It was first published online on November 1st. On November 2nd, there was a whole-page article in the paper version in the weekend edition. In Innherred, local newspapers wrote about the study to increase the motivation of the random sample, plus recruit others in the non-random sample. *Frostingen* wrote three articles (19.09.2019, 26.09.2019, and 03.10.2019), *Snåsningen* wrote one article (02.10.2019), and *Inderøyningen* wrote one article (27.09.2019).

3.5.4.3 Invitation Letter

The invitation letter was based on the invitation letter from the NNTS. Still, we spent a lot of time working on the wording of the text, aiming to appeal to the respondent's sense of altruism and personal gain in participation. The goal was to make it look professional and official but friendly. Furthermore, we wanted to have the logos of the project and partners in the letter to show the project's legitimacy.

The text in Trondheim II was shorter than in Trondheim I (see Appendix C for Invitation letters). In the first pilot, the letter included a 2-page information letter (See Appendix D for Information letters). In Trondheim II, the information letter was included in the invitation letter as a link to an online web page to make it more appealing. We wondered if there were too many pages and too much text in Trondheim I, producing some of the sampled persons throw away the letter without reading it.

Shortening the text as much as possible was to reduce the perceived response burden (we suspected that the first invitation letter had too many pages and too much text). The goal was to find a good balance between giving the respondent enough information and reducing the response burden.

In the first letter, we included a QR code. We had different QR codes in Trondheim I to differentiate the recruitment method. However, in Trondheim II, we decided rather to include a question about how the respondent was recruited. Thus, the QR code was removed and replaced by a box with information about the lottery (we still used QR codes in the flyers in Trondheim II). We hoped the lottery would incentivize some to participate.

In Innherred, 6000 received a paper letter with information about the study. 6450 received the same letter electronically via the digital mailbox system *Digipost*.

3.5.4.4 Crowdsourcing

It was optional for non-sampled persons to participate in Trondheim I, II, and Innherred. We used multiple recruitment methods to get as many as possible to download the app. In Trondheim I and II we handed out flyers printed on colored paper to make them stand out more. The size was A6, and we distributed approximately 1000 flyers in mailboxes or handed them out in public. Information was also shared on social media (personal accounts, local public transport institutions' social media) and NTNU's Intraweb. The results from recruitment are presented in paper III, but a description of the material can also be found in the Travelviewer report on recruitment strategies (Tørset and Svaboe, 2020a).

3.5.5 Representativity

Regarding representativity, I have estimated response rates, studied the distribution of gender and age, and compared the results with SSB distributions. R Studio was used to facilitate some of the data sets from Trondheim I. I used Stata MP to do the analyses. The response rates are reported and discussed in paper III. The estimation method is described here. The distribution of age, gender, and descriptive statistics is described and discussed in this section.

Regarding the estimation of response rates, I used the method provided by Richardson, Ampt, and Meyburg (1995), which is dividing the number of "acceptable responses" by the *net* sample size (gross sample size minus sample loss). Acceptable responses were the number of respondents who reported at least one day (Table 12). Sample loss was the number of letters returned to us. In the student pilot, we had a convenience sample, thus, there were no ways of estimating a response rate. The response rate for all pilots was low

and is discussed in paper III and Chapter 4 (Results). A potential explanation for the low response rate is provided in paper IV.

Table 12 Number of acceptable responses to estimate response rates in paper III

Study	Acceptable responses (N)
Trondheim I	81
Trondheim II	488
Innherred	652

When evaluating the representativity of the samples from the TravelVu 2019 pilots, I compare the random samples with register data, and test if age and gender distributions are significantly different from population distributions. I studied age and gender distributions for these samples because I could not access education level or income data on a municipal level for the Innherred municipalities. Tables 13, 14, and 15 present age and gender distributions (percent) for the random samples in Trondheim I, II, and Innherred, SSB distributions (Statistics Norway, 2022), and the results from chi-square goodness of fit testing. I have also included distributions of the non-random samples.

In Trondheim I, the recruitment method was identified by which survey the respondent participated in. 258 reported travel for at least one day. 81 respondents participated in the survey open for the drawn sample. These are defined as "random." 177 participated in either of the other two surveys and are categorized as "non-random." When discussing representativity, those that did not reply to the question on gender and/or age were coded as "missing." This gives 78 random and 174 non-random respondents. The distributions and chi-square goodness of fit test results for Trondheim I are presented in Table 13.

Table 13 Distributions[14] (percent) Trondheim I and SSB + chi-square goodness of fit test with SSB distribution as ref.

	Random sample						**Non-random sample**		
	Men		**Women**		**Total**		**Men**	**Women**	**Total**
Age	T I	SSB	T I	SSB	T I	SSB	T I	T I	T I
18-24	10 %	16 %	16 %	15 %	13 %	16 %	7 %	6 %	6 %
25-34	13 %	26 %	26 %	24 %	19 %	25 %	31 %	36 %	33 %
35-44	20 %	19 %	18 %	19 %	19 %	19 %	30 %	37 %	33 %
45-54	38 %	18 %	13 %	18 %	26 %	18 %	17 %	12 %	14 %
55-64	10 %	14 %	18 %	15 %	14 %	15 %	12 %	8 %	10 %
65-70	10 %	7 %	8 %	8 %	9 %	8 %	4 %	2 %	3 %
Total	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
N	(40)	(71857)	(38)	(67317)	(78)	(139174)	(84)	(90)	(174)
Chi2		13.15		.9		4.2			
Df		5		5		5			
p-value		.22		.970		.521			

[14] Using the 2019 municipal boundary.

Table 13 shows that more women than men participated in Trondheim I (random and non-random sample). Comparing the random sample with the population description for Trondheim (SSB, Table 13), the overall age distribution amongst the female participants is pretty similar to the SSB distributions. The only exception is the age group 45-54 years, which is somewhat underrepresented. For the men, however, the two youngest age groups (18-24 years and 25-34 years) appear to be underrepresented in the data material. The age group 35-44 is relatively well represented. The age group 45-54 is overrepresented, and the age group 55-64 is underrepresented. The age group 65-70 is overrepresented.

The chi-squared testing shows that there were no significant differences between SSB distributions and Trondheim I distributions for men, women, or the total sample, which is reasonable considering the similar distributions. However, the small random sample, and high unit nonresponse, indicate representativity issues in the data material.

In Trondheim II, the question of recruitment was included in the survey. 865 reported at least one day of travel. 488 respondents said they were recruited through means used to contact the drawn sample and are thus categorized as “random.” 377 reported they were recruited other ways and are categorized as “non-random.” Those that did not respond to the question of gender or year of birth were coded as “missing”. This gives 488 random and 358 non-random respondents. The distributions and chi-square goodness of fit test results for Trondheim II are presented in Table 14.

Table 14 Distributions [15](percent) Trondheim II and SSB + chi-square goodness of fit test with SSB distribution as ref.

	Random sample						**Non-random sample**		
	Men		**Women**		**Total**		**Men**	**Women**	**Total**
Age	T II	SSB	T II	SSB	T II	SSB	T II	T II	T II
18-24	6 %	16 %	12 %	15 %	9 %	16 %	15 %	12 %	14 %
25-34	17 %	26 %	21 %	24 %	19 %	25 %	26 %	26 %	26 %
35-44	22 %	19 %	18 %	19 %	19 %	19 %	30 %	25 %	28 %
45-54	24 %	18 %	24 %	18 %	24 %	18 %	14 %	21 %	17 %
55-64	21 %	14 %	18 %	15 %	20 %	15 %	11 %	10 %	10 %
65-70	10 %	7 %	8 %	8 %	9 %	8 %	4 %	5 %	5 %
Total	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
N	(220)	(71857)	(268)	(67317)	(488)	(139174)	(189)	(169)	(358)
Chi2		37.94		11.52		40.17			
Df		5		5		5			
p-value		.000		.042		.000			

Looking at the random sample distribution, the age group 18-24 is underrepresented in the data material for men, women, and the total sample. However, men are more

[15] Using the 2019 municipal boundary.

underrepresented than women in this age group. The age group 25-34 is also underrepresented for men, women, and total, but men are again more underrepresented. Men are overrepresented in the data material in the age group 35-44. Women are pretty representative of this age group. For the total, this age group is quite representative, when compared to SSB distributions. Age groups 45-54 and 55-64 are overrepresented for men and women. Age groups 65-70 are slightly overrepresented among men but representative for women.

The chi-squared testing shows that all the samples from Trondheim II are significantly different ($p<0.05$) from the SSB distributions, indicating that they are not representative of the Trondheim population when it comes to age and gender.

Table 15 presents the results for Innherred (Levanger, Steinskjer, Verdal, Inderøy, Snåsa, Frosta, Verran). 652 were categorized as "random," and 285 were recruited mainly through crowdsourcing methods and are classified as "non-random." In addition, those that did not respond to the question of recruitment, gender, and/or age are coded as missing (N=69) when studying representativity[16]. This resulted in 876 respondents for the representativity analysis, whereas 613 (70 %) were "random" and 263 (30 %) were "non-random," i.e., crowdsourced.

Table 15 Distributions [17](percent) Innherred and SSB + chi-square goodness of fit test with SSB distribution as ref.

	Random sample						**Non-random sample**		
	Men		**Women**		**Total**		**Men**	**Women**	**Total**
Age	Innhrd.	SSB	Innhrd.	SSB	Innhrd.	SSB	Innhrd.	Innhrd.	Innhrd.
18-24	2 %	15 %	7 %	14 %	5 %	14 %	3 %	8 %	6 %
25-34	12 %	18 %	22 %	18 %	18 %	18 %	11 %	20 %	16 %
35-44	21 %	17 %	17 %	17 %	19 %	17 %	38 %	27 %	32 %
45-54	26 %	20 %	27 %	21 %	27 %	21 %	28 %	27 %	27 %
55-64	27 %	19 %	18 %	20 %	22 %	19 %	17 %	16 %	17 %
65-70	12 %	11 %	9 %	11 %	10 %	11 %	3 %	2 %	2 %
Total	100 %	100 %	100%	100 %	100 %	100 %	100 %	100 %	100 %
N	(259)	(23913)	(354)	(22825)	(613)	(46738)	(115)	(148)	(263)
Chi2		51.65		24.79		51.76			
Df		5		5		5			
p-value		.000		.000		.000			

Comparing SSB distributions with the Innherred random sample in Table 15, we can see that women are generally overrepresented in the data material. Furthermore, the youngest (18-24) age group is underrepresented in the data material for men, women, and the total sample. Age group 25-34, the male portion is underrepresented, and women are

[16] They were not all excluded in all estimations, such as response rates.
[17] Using 2019 municipal boundaries.

overrepresented. In the age group 35-44, men are overrepresented. This age group is quite representative of women. The age group 45-54 is overrepresented for both men and women. The age group 55-64 is strongly overrepresented amongst men. For women, this age group is slightly underrepresented. Interestingly, the eldest age group (65-70) is relatively well represented in this study regarding men. Women of this age group are underrepresented.

Overall, the Innherred random sample does not appear representative, and sample weights are necessary when estimating key travel behavior metrics. The differences between the Innherred sample and SSB distribution are statistically significant, with p-values<0.05.

When we look at all three studies (Trondheim I, II, and Innherred) together, we can see that the youngest age groups are the hardest to reach in the random sample. That being said, they are a higher share of the sample among the non-random sample for Trondheim. This is especially true for men. The crowdsourcing methods probably reached a different type of people than the random sample recruitment. In Innherred, young people were hard to get, no matter the recruitment method. The main difference between Trondheim and Innherred is that Innherred is more rural than Trondheim.

Furthermore, the eldest age group was quite representative in our studies. Perhaps this is because of a higher motivation to participate in surveys among this group.

3.5.6 Reliability and Validity

Since the app tracks movement, starts, and stops, it reduces the issue of respondents having to interpret the trip definition, although they need to understand the trip definition to validate their trips correctly. However, the low response rate is a reason for concern, which is discussed more in papers III and IV. Technical issues were also a challenge, which could have affected the responses. We may have lost some respondents in the pilots due to the software not working correctly, either due to the respondent not having the necessary skills to use it or technical issues. Still, this thesis focuses on the methodology, not the actual travel behavior. Thus, this does not pose a direct problem for the papers or thesis. Due to software updates, the main “challenge” is whether the instrument is the same in all data collections. TravelVu was improved for each data collection (for example, bugs were removed, and the interface was improved). Then again, from a quality perspective, it is better to use an improved app than to continue using an older version purely for comparability reasons.

3.5.7 Ethics, Privacy, Data Processing, and Data Storage

Tracking technology, and its use in research, is controversial to some. I have not collected what is officially considered sensitive information (e.g., sexual orientation, health status, etc.), but I have processed person-identifying data. Further, what is regarded as sensitive information to one person can vary greatly. For example, a postal code can be very sensitive to a person in the witness protection program. Therefore, it has been essential that all participation was voluntary and that the participants had complete control of their data.

Before data collection, the projects were notified to the Norwegian center for research data (NSD). The processing of personal data was done according to the Personal Data Act and the General Data Protection Regulation (GDPR). All pilot participation was voluntary, and all those who participated in the pilots received an information letter informing them of their rights. The information letter was made available in the app, on the project webpage, and/or on paper letter (for the random sample). Participants could withdraw from the study by reporting an individually randomized id-number (the only way to id them directly). The id-number was unique for each download and not connected to the phone number or any other direct identifier. After data collection, the data material was anonymized, and returned invitation letters were destroyed. Directly person-identifying information was deleted. The end-points (activity locations) were aggregated into a basic statistical unit (grunnkretsnivå). The data was stored securely, and only a limited number of people (authorized project members) had access to the anonymized data.

Because Trivector processed data on behalf of NTNU, an agreement was made and signed before data collection started. A legal practitioner employed at NTNU was involved in this process to ensure that the agreement was in line with GDPR and Norwegian laws and regulations. The deal described what Trivector could and could not do with the data.

3.6 Focus Groups

The focus group interviews were conducted in early 2017. Transcriptions from these interviews are used in papers III and IV. These interviews aimed to (1) gather information about students' experiences with surveys and interviews and (2) discuss potential ways to increase participation in travel surveys. Focus groups were chosen because it is an efficient way to collect data (Tjora, 2021). The informants were students at NTNU who had studied for at least one semester. They were recruited in lectures and social media. The informants (21) were divided into three groups (see Table 16).

Table 16 Description of Groups and Informants

Group	Informants (N)
Group 1	8
Group 2	8
Group 3	5

The interviews were structured into three parts. The first part included warm-up questions, the second part included questions about experiences, preferences, and opinions with surveys and research in general, and the third part was about the use of smartphone technology. The interviews lasted 1-2 hours, and stimulus materials (a presentation of Google Location History) were used to discuss the potential of tracking at the third part of the interview. The informants received an information letter before the discussion began, and the interviews were recorded. A notetaker was present at each interview. Consent was collected by getting a signed form from each participant at the beginning of the interview. They were informed they could withdraw from the study at any time without giving a purpose. After the data collection, the interviews were transcribed and anonymized.

The focus group interviews were one of the first data collections we did in the SmartRVU project before we decided to use TravelVu in data collection. The results were valuable in planning the Student pilot (see 3.5.2) and thus all future STS data collections[18].

3.7 Personal Interviews

After the NNTS document study, technical test, focus groups with students, three data collections with TravelVu, and an enquête, I developed several theories about recruitment methods, smartphone use, and attitudes towards surveys. However, I only interviewed students. In the NNTS, the population is the general population of Norway. I needed to collect data about the general public to test my theories. The problem is more people say "no" than "yes," and thus, "normal people" are not inclined to participate in surveys. And this creates a big problem: How do I study and learn more about "normal people" when the "normal person" does not like to participate in surveys?

The choice was to conduct qualitative personal semi-structured interviews. Qualitative interviews aim not to quantify a phenomenon's prevalence and scope but to *understand* it (Leseth and Tellmann, 2014). The purpose of the study was to understand what we, as researchers, have to work with when it comes to motivation for participation and the potential of a smartphone app. The format of a qualitative interview differs from a traditional

[18] Some results not included in paper III or IV can be found in a SmartRVU report (Svaboe and Tørset, 2017).

survey, and I could go more in-depth with the questions. Furthermore, studying the problem qualitatively makes it possible to distance me from the typical survey situation somewhat.

3.7.1 Data Collection

As a rule of thumb, it is customary to stop interviewing new informants when the interviewer experiences a saturation of information (Tjora, 2021). I decided to continue to do interviews until I did not find new information (the saturation point). After 4-5 interviews, the same stories and opinions started to repeat themselves, and for each new interview, fewer and fewer new elements emerged. Thus, I decided to stop after ten interviews, because I experienced information saturation (Fusch and Ness, 2015). The informants were from different geographical places in the country and were in the age gap of 30-81. I interviewed five men and five women.

The data material is notes from 10 semi-structured interviews. Personal interviews are usually conducted face-to-face. However, due to restrictions, the data collection happened during the COVID-19 lockdown, so it had to be done digitally or by phone. I used Zoom and Teams in 8 of the interviews. 2 of the interviews had to be done using the telephone. The interviews lasted between 30-74 minutes. I decided not to record the interviews due to privacy issues and time limitations and used a notetaker instead.

I wanted “normal people,” but they had to fulfill specific requirements:

- Don’t work at a university
- Not students
- At least 30 years old
- Owns a smartphone

I did not want anyone that worked at a university because they are more likely to participate in research and are probably more interested in research in general. Researchers are not an under-represented group in data sets and do not necessarily represent the Norwegian population. Furthermore, people with high education are over-represented in the NNTS.

I also did not want to interview students because I had already done so in a previous study. The goal was to collect information about the general public and find out if some of the results from the focus groups were transferable to other groups. Thus, students were eliminated.

The minimum age was set to 30 years because they needed *some* life experience. The probability that the informant had been contacted to participate in a survey is high at that age.

Lastly, the informants were required to own a smartphone because one of the topics I wanted to discuss was the use of smartphones and GPS technology in travel surveys and data collection.

The informants were recruited through friends and acquaintances (social networks). There are two big “pros” of using social networks: 1) It is easier to “target people” who are part of a specific group, and 2) It is cheaper. The big con is that they are closer and non-random. However, generalization is not a goal in qualitative research, and I was more interested in testing my theories than generalizing. So, a research assistant and I asked friends, family, acquaintances, and co-workers to share information about my study. A text/post about the study was also shared on selected Facebook groups.

3.7.2 Interview Guide

At the beginning of the interview, the interviewer shared some relevant information with the informants. First, they were informed of their rights. Then they were encouraged to express their opinions and feelings freely and told that there were no right or wrong answers. They also got an explanation about the PhD-project and what the results would be used for. The questions in the interview guide (see Appendix B.2) were structured into five parts based on themes: A) Introduction and warm-up questions, B) Surveys in general, C) Travel surveys and apps, D) Register data, and E) Closing questions.

3.7.3 The Interviewer’s Role and Personal Adjustments

The quality of interviews depends on the trust between the researcher and the informant. I tried to make the interview as comfortable as possible so that it became more of a conversation than an interview. This is because it had to be done in a somewhat unnatural way, and the anxiousness of doing it digitally had to be dealt with.

I found it essential to specify that I did not work in app development and that it was not my goal to collect data using apps early in the interview. For example, one informant was afraid that s(he) had offended me for not approving of using such technology. I assured them that the goal was to find the best way to collect the information, not to force anyone to use a particular tool or to promote the app. Afterward, the informant let loose more and talked more freely. It was good to use a probe to ensure that all informants knew what I was asking about regarding travel survey apps. However, it does create a risk of the informant believing that the interviewer has a personal interest in the app and tries to be “kinder.” Nevertheless, I did not find that those that were skeptical held back on their negative opinions, and those that were positive about using such technology were very enthusiastic.

3.8 Analysis of Qualitative Interviews

The approach to analyzing and coding the data material was *thematic* and *semantic* (Braun and Clarke, 2006). Although the theoretical framework was not set in stone before coding and analyzing, the coding process was deductive (Leseth and Tellmann, 2014; Azungah, 2018). A deductive approach to analyzing data means approaching the data material with some general concepts and using these to explain and analyze (Leseth and Tellmann, 2014). These "pre-defined" concepts were rough versions of the two value dimensions "fear of risk" and "technology interest."

Before the analysis, I suspected there was a fear among some people connected to the data collection and that some might have issues with the technology. As a result, I made some general observations, which I knew could provide a framework for the analysis. However, the theoretical framework of DT was chosen after the coding so it was not a purely deductive analysis.

I suspect a more inductive approach would have resulted in a similar conclusion because the varying use of smartphones and fear of mishandling of data were recurring themes in all the interviews.

3.8.1 Typology Development and Ideal Types

Ideal types are one-sided exaggerations aiming to capture an essence (Ritzer and Stepinsky, 2014) and were originally developed by Max Weber (Hekman, 1983). Since the point is to capture the heart of a social phenomenon, they should not be treated as mirrors of the real world. Ideal types can be understood as "extremes" or "synthesized versions." I use the concept of ideal types in paper IV to explain the different reactions to smartphone travel surveys. More specifically, I use ideal types to develop a typology of responses to smartphones, visualized using a four-field model (see Figure 4). Typologies are schematic categorizations of items, phenomena, findings, etc., and I used Tjora's (2021) typology description as a basis for developing my model.

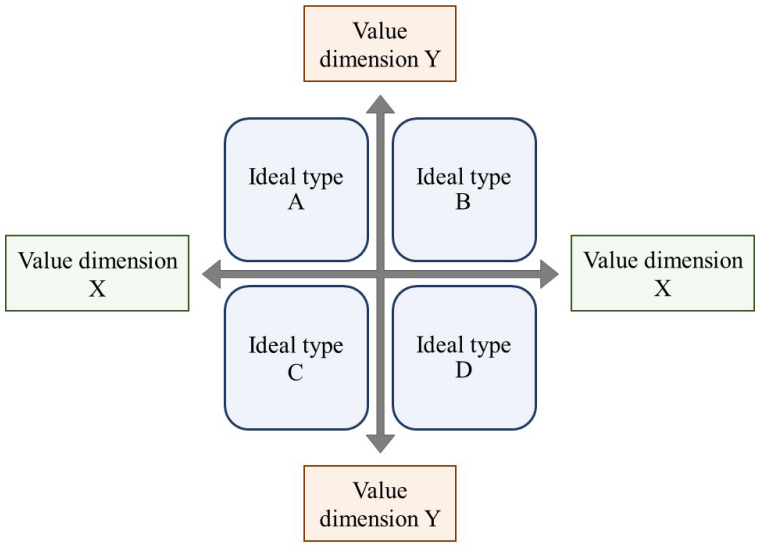

Figure 4 Visualization of a typology and how ideal types are used in paper IV

In paper IV, the typology has two theoretical dimensions (value dimensions) and four ideal types. Ulrich Beck's 'risk society' was used to develop the value dimension concerning risk (Y-axis) in the typology. Diffusion theory was used to develop the value dimension concerning reactions to new digital technology (X-axis). The final version of the typology is presented in paper IV and Chapter 4 (Results).

3.9 Limitations

Here I discuss potential weaknesses of the methodological choices and some barriers I met during data collection.

3.9.1 Document Study

The limitations of a document study/analysis as a method are that they can be limited or partial, they are written for a purpose, and it can be challenging to assess causal relationships (Robson, 2002). For example, the key reports mainly collect information about routines, and sometimes routines deviate from practice. Thus, relevant information about the practice might exist that is not documented. Furthermore, some countries were easier to collect methodology information on than others due to varying degrees of openness of possible weaknesses and inference in their NTS, and I experienced language barriers (German and French). Most of the public documentation in NTSs is written in the native language, and they only have a summary in English. Thus, it is possible that some relevant information is not included for the French and German NTS.

3.9.2 Chi-squared Testing

The chi-squared test does have some issues when analyzing large samples, and the NNTS data does have quite large samples. However, it was the most fitting test given that level of education is a categorical variable. Furthermore, I tested for the national sample (NS) and the entire sample (All). The national sample is relatively small in the NNTS compared to the entire sample, so the risk of sample size affecting the results in those samples was lower. As such, I believe it was the best statistical test despite its potential weakness. For the goodness of fit testing of TravelVu samples, the shares of each group were small, especially for Trondheim I. However, the expected values were over 5, and the observations are independent. Thus, despite the small sample size, I decided to do the test and include the results.

3.9.3 Recruitment in TravelVu Pilots

The potential limitations regarding the recruitment are mainly the fact that we could not test all the recruitment methods available, which was a cost issue. A vital recruitment method I wanted to test was the effect of interviewers as motivators and recruiters and having more people helping respondents install the app. An incentive I would like to have tested is a pre-gift with the invitation letter (e.g., stamps, reflector, stickers, etc.). Testing the effect of sending a gift without demanding anything in return would be interesting.

3.9.4 Qualitative Interviews

The risk of bias is that those participating in research are generally more interested in research. Furthermore, it is possible that the informants withheld some negative experiences with researchers since I worked at a university during data collection. It is also possible that the personal interviews were affected by the launch and media coverage of the Norwegian COVID-tracing app.

4 Results

This chapter presents the main results of the research (summary of the papers). It is advised to read the papers for a more in-depth explanation of each issue.

4.1 The Current State of the NNTS

Based on a document study, a quantitative analysis of NNTS 2016-2019 key metrics, and comparing the NNTS samples with SSB register data, the main results from paper I are:

- The response rate is low and declining
- The duration of completing the survey is long, causing a high respondent burden
- There are signs of CAWI and CATI respondents reporting different travel behavior (i.e., mode effects) after the implementation of CAWI in 2016
- Biased geographic sampling and representativity challenges have been identified due to the increased use of regional add-ons
- The declining trip rates in recent years appear to be caused by survey design choices, not a change in travel behavior
- Since the methodology change, there has been an increase in the share of immobiles. Furthermore, there are more immobile respondents among CATIs than CAWIs, indicating a higher percentage of soft refusals (i.e., respondents reporting 0 trips to shorten the interview duration) among CATI respondents
- There is an over-/underrepresentation of certain socioeconomic/sociodemographic groups in the data

Representativity in travel surveys is ensured in two steps: 1) recruitment and 2) weighting. All of the identified issues cannot be corrected through weights. The NNTS survey design needs to be changed to reduce the probability of sample selection bias. In paper I, we also discuss possible solutions to these challenges:

- Reducing the questionnaire
- Use more register data
- Improve training and supervision of interviewers
- Improve recruitment work
- Improve overall survey design
- Ensure methodological awareness of all those involved in the planning and execution of the NNTS

4.2 NTS Methodology and Quality in Six European Countries

In paper II, we discuss the survey design of 6 NTSs (Norway, Denmark, Sweden, France, England, and Germany), the challenges identified, and how they were attempted to be mediated. The paper shows that although the countries have different ways of conducting their NTS, all struggle with declining response rates.

Regarding the transportation-specific measures of quality, paper II shows

- There is an underreporting of shorter trips, and sometimes, weights are used to mediate this error. Multiple countries are experiencing a decrease in trip rates.
- Sweden, Denmark, and Germany are experiencing an increase in the share of immobile respondents on the day of reporting. However, whether it is a problematic high share depends on the reference value of "quality," making it a challenging measurement. England did not have open-access information on the percentage of immobile respondents. Still, English documents included a discussion of an increase in immobile respondents and how it has become an issue in the English NTS. Norway experienced a rise in immobiles after the methodology change in 2016. Whether the French and Norwegian NTS has a fair share of immobiles depends on which standard one uses.
- Representativity in the sample is challenging for all countries, although the countries have varying goals of representativity and variable use of regional add-ons. Sampling strategies such as stratification and oversampling are used in the HTSs and ITSs studied to ensure data from specific geographical areas (e.g., the English NTS oversampling London and regional add-ons in Norway and Germany).

Regarding data collection tools, most countries have reviewed or conducted pilots using tracking technology (GPS device or smartphone). Furthermore, CAWI is becoming a more popular option for self-reporting trips, usually as a part of multi-mode solutions for data collection. CATI is decreasing in use.

This paper also revealed the issue of transparency in NTS documentation; the quality and detail of documentation varied considerably between years and countries.

4.3 Recruitment Strategies

Paper III presents findings concerning recruitment to a smartphone app TS. The main findings are that smartphone app travel surveys result in low response rates, and most likely, lower than in a TS using traditional methods. Furthermore, there were signs of significant respondent burden to some potential respondents because they could not use

the app or experienced technical issues during data collection. This indicates that those participating in a smartphone-based TS might not represent the entire population.

In the paper, we discuss the effectiveness of initiatives to increase participation and recruitment methods (presented in Table 17). The procedures were categorized by which phase of the TS they were relevant.

Table 17 Initiatives to improve the response rate and increase the sample size (source: Table 5 in paper III)

Why	How	Effect	Quantifiable?	Phase
Name recognition	SmartRVU e-mail, web page, and logo	Unknown	No	Preparation
Show professionalism	Translation of all material to Norwegian (also app) Design of material Web page SmartRVU e-mail NTNU's and partners' logo on invitation material and web page Impeccable language	Unknown	No	Preparation
Reminders	SMS to random sample	Immediate strong	Yes	Data collection
	Push message in app to all users	Medium	Yes	
Incentives	Gift card (monetary)	Unknown	No	Data collection
	Appealing to altruistic motivation in invitation material (non-monetary)	Unknown	No	Data collection
Reduce respondent burden	Reduce number of reporting days	Weak	Yes	Invitation
	Flexibility in day of reporting	Weak	No	Data collection
	Reduce background questions Shorten letter	Weak	No	
	Tracking technology YouTube instructional video Support phone number	Variable	Yes	Data collection
Create media attention	Advertisement	Weak	Yes	Invitation
	Newspaper article	Medium	Yes	Invitation
	Ambassador (famous person)	Unknown	No	Invitation
Increase sample	Crowdsourcing	Unknown	No	Invitation

Although we did many initiatives to increase participation, the response rate was low for all pilots (4.1-5.2% response rates[19] for the random samples), and we found skepticism toward the technology because of the tracking aspect. We argue that methodological awareness is essential when planning and conducting a travel survey.

[19] The other test sites in the Travelviewer project had similar response rates.

4.4 Understanding Nonresponse in Smartphone Travel Surveys

Almost “everybody” owns a smartphone in Norway today. However, it is used differently, and paper III showed that owning a smartphone and having a high penetration rate of smartphones does not automatically mean more accessible data collection in a smartphone-based travel survey. As a result, paper IV focuses on understanding why, despite so many owning smartphones, a smartphone solution might still be sub-optimal in a travel survey context.

A typology of responses to smartphone apps was developed using sociological theory, a privacy definition from psychology, and data from two qualitative studies (Figure 5). There are two main reasons technology presents recruitment challenges: fear of risk and technology interest. Using a smartphone as a tool for data collection pushes away those afraid of their data being abused and excludes those not proficient in the technology.

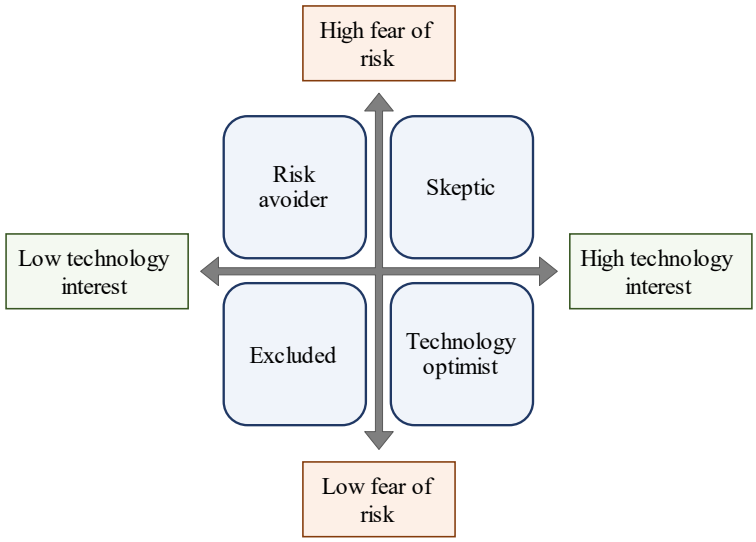

Figure 5 Typology to explain respondent behavior (source: Figure 3 in Paper IV)

It is easy to understand why the response rate was so low in our smartphone-based TSs: only the Technology optimist would participate in a smartphone TS. The Risk avoider would not participate in any travel survey due to high fear of risk and low technology interest. The Skeptic has the necessary skills to participate in a smartphone TS (high technology interest) but has an increased fear of risk and would thus not participate in a smartphone TS. Finally, the Excluded have a low fear of risk but is unable or unwilling to use the technology (smartphone app) and would thus not be able to participate in a smartphone-based TS.

5 Discussion

In the introduction, I presented three research questions: 1) What is the current state of national travel surveys? 2) How does using smartphone app technology in travel behavior research affect data quality? and 3) What should NTS practitioners do to mediate the challenges regarding NTS quality? In this chapter, the research questions are discussed. The discussion is based on the papers in the thesis, Chapter 2 (Background), and Chapter 4 (Results).

This chapter is structured as follows: I first discuss each research question based on the results of the papers and literature presented in the papers and the cover article (5.1-5.3). Second, I discuss the consequences of the thesis plan (5.4). Thirdly, I discuss the implications of limitations (5.5). Fourth, I present some identified areas for future research (5.6).

5.1 The Current State of National Travel Surveys

Paper I and II contribute to answering this research question. Previous research and results indicate that non-response is an issue “everywhere.” All countries in the analysis in paper II had some challenges regarding nonresponse. Furthermore, when looking at the literature, this is seemingly a challenge in countries not studied. Underreporting of trips, either due to methodological decisions, respondents not understanding the trip definition, or respondents aiming to shorten the interview, appear to be a challenge.

However, not all countries are equally transparent about their challenges (see paper II for discussion). Representativity challenges and quality were discussed in the 2000s (and some still do), but it has gotten less attention in the past ten years. However, when NTSs depend on tendering in the data collection process, documentation of the process is vital when new persons and institutions enter the project. Otherwise, it can cause comparability issues and disruption of the time-series due to a lack of knowledge on methodology (i.e., structural changes).

Furthermore, what became clear in paper I, and even more evident in paper II, when the issue of transparency became more prominent, is that the key report written in conjunction with the NNTS is essential for ensuring quality in the NNTS; Various institutions and organizations use the NNTS datasets to make predictions, estimate key metrics, etc. (i.e., transport modeling). For these modelers, the key reports are the primary source of information on how the data is processed, coded, and collected. Furthermore, many people working in research and travel surveys in Norway reference the key reports when discussing travel behavior. Policymakers reference the key report when arguing for a

specific type of policy. Thus, the key reports must have information and a decent description of the methodology and potential limitations.

Another trend identified when reviewing NTSs (papers I and II) was that more and more countries are choosing multi-mode solutions for data collection to mediate non-response and other representativity issues. Although multi-mode solutions make it possible to reach more diverse respondents and create flexibility for the respondent, it also has unintended adverse side effects that affect the data (i.e., mode effects). Thus, it is essential to be aware of this before data collection and have measures planned to mediate this if one wishes to use this solution.

Finally, significant survey design changes appear difficult (but not impossible) due to the wish to preserve time-series. Although some countries have changed methodology, most countries continue in more or less the same way as always to ensure comparability over time. On the one hand, making change difficult is a good thing because it ensures comparability, and change for change's sake is not necessarily a good thing. On the other hand, change is perhaps necessary if the data material is of such low quality that it is not worth comparing with previous years. As such, the difficulty of change can be understood as somewhat of a double-edged sword.

5.2 Smartphone app Technology in Travel Surveys and Effects on Quality

Smartphone app technology has a lot of potential in theory (discussed in papers III, IV, and Chapter 2): The data material is much more detailed and does not rely on human memory. However, the response rate is usually lower than in travel surveys with traditional methods, and there are data comparability challenges. Furthermore, the qualitative interviews revealed that some respondents are more likely to participate in a smartphone-based TS due to their interest in the technology. Thus, introducing a smartphone app solution into the NTS can have unintended side effects. If one chooses only to use a smartphone app during data collection, two things can happen: firstly, there can be an overrepresentation of respondents that previously never participated in an NTS. Secondly, one excludes groups that previously participated because of the technology.

On the one hand, the first point means getting new respondents, which is potentially a positive thing. However, the second issue can cause trouble for the time-series, because one potentially studies a completely different population segment in a changing methodology. This, in combination with a lower response rate, means that in a smartphone app-based NTS, one must expect, and deal with, a lower response rate and new types of noises/interference in the data material.

A less dramatic solution would be introducing a smartphone app as an option for data collection method to the respondents. Then those interested could use it (i.e., multi-mode solution). This could potentially make it possible to recruit new respondents without eliminating other respondents. There are, however, a few drawbacks to this. Firstly, those that use the app will probably report a different travel behavior due to the administration method (i.e., mode effects). Those who analyze the data must be aware of this in such a solution. Furthermore, as shown in paper IV, some people are more inclined to participate with a smartphone solution due to their interest in personal statistics and general interest in the technology. Their travel behavior might be different from those choosing other reporting tools.

Nevertheless, independently of choosing a purely smartphone-based TS or multi-mode solution, the TS's success depends on excellent technology. If the app is terrible (e.g., glitching, user-unfriendly), it can cause nonresponse issues and increase the respondent burden.

5.2.1 Utilizing the Technology in Travel Behavior Research

Based on Tables 13-15 (Methodology) and results from papers III and IV, getting a representative sample using only smartphone technology is challenging at best. However, this does not mean that smartphone app data don't have a place in transport research and transport policy planning. Suppose the travel behavior researcher accepts that other modes of data collection provide different perspectives on the same theme (a different version of the same "picture"). In that case, there are many potential ways in which this technology can be used.

One way to utilize smartphone technology is to gain a greater insight into mapping *shortcuts* that are not on any official map. A significant strength of smartphone app data is the ability to study respondents' chosen routes. One does not need a representative sample to identify the existence of shortcuts. However, if one studies tracking data, it is much more accessible to study the route choice of pedestrians and cyclists.

Another potential use is to increase the understanding of the shortest trips. Short trips are notoriously under-reported in traditional travel surveys (as identified in papers I and II), and it does not appear to be a simple fix for this. They are regarded as unimportant, not a trip, or forgotten by the respondents. In a tracking app, many of these trips are automatically collected. Perhaps studying the short trips of respondents in a smartphone app travel survey could provide new insight into the topic.

To summarize, tracking technology's main advantage is getting a deeper understanding of movement. More specifically, it opens the possibility to study behavior that people cannot necessarily recreate based on memory.

5.2.2 Utilizing the Typology of Reactions to Smartphone Apps in Travel Behavior Research

On the practical level, the typology (paper IV) can be useful in the choice of data collection tool, developing recruitment strategy and recruitment material.

For those considering using a smartphone in data collection, the ideal types can be used to understand why it can sometimes lead to nonresponse and negative reactions. For those already using such a solution, these ideal types can be used in the recruitment process by developing recruitment material that incentivizes those with high technology interest to participate and reduce the fear of risk of participation. However, it is important to point out that some will never accept a tracking solution out of fear of risk or lack of knowledge. These need to be studied in alternative ways. However, for experimental studies or studies where the population is people with high technology interest, knowledge on how to utilize this interest in the recruitment phase can be useful.

5.3 Advice for NTS Practitioners

5.3.1 Survey Design

Chapter 2, paper I, and paper II illustrate the importance of planning and how choices made before data collection can affect the data. The most important advice is to take time to develop a good survey design and not take shortcuts in the early stages. Furthermore, it is key to have clear documentation guidelines in future tenders if there is a change in data collector. This will reduce the chances of quality issues due to structural changes. Finally, regarding the questionnaire, I give the following advice:

- Those responsible for the questionnaire should test it themselves by conducting telephone interviews – that way, they get a better grasp of the practical issues interviewers must deal with.
- The questionnaire development team needs qualified people within transportation and survey methodology/design. Both fields are necessary to ensure high-quality travel data.

The importance of documentation is discussed in papers I and II. To ensure the long-term quality of the NTS, it is necessary to improve the documentation and increase the transparency of data collection. If the meta-data is improved, it can reduce the risk of those responsible for the NTS misunderstanding something and making the wrong estimates in

the future. One way to do this is to implement the requirement of having an independent quality controller of the data material. Regarding defining the aim and scope of the NTS, I give the following advice:

- Be aware of the most crucial goal of the NTS – is it to get information about the national travel behavior or to get both national and regional travel behavior simultaneously? If the NTS tries to be two things simultaneously, it risks failing at both.

Regarding the preservation of the time series and increasing the quality of the NTS, I give the following advice:

- Keep collecting data using traditional methods (to avoid the exclusion of specific population segments and ensure comparability over time)
- Do more experiments with sub-samples – learn more about those you study
    - Interview interviewers – what are their experiences?
    - Reduce the questionnaire and simplify the questions – the current version is too long, and the wording is complicated, potentially confusing the respondent.
    - Identify efficient recruitment methods for the first contact, such as improving the design of the invitation letter and maybe even a pre-participation gift.
- Interviewer training programs and interview guides need reviewing and improvement – ensure that those conducting the interviews have the necessary resources and tools to motivate participation, clear up misunderstandings and reduce soft refusals. A primary advantage of CATI is that interviewers can inspire participation. However, this is only possible if they get the necessary training and tools.
- Use reminders efficiently

In the cover article and papers, I use literature from travel survey methodology and survey research because travel surveys can be understood as a “category” of surveys. This means that a “good survey design” in the travel survey context means a methodologically aware (survey research and transportation engineering) survey design; a good survey design has both minimized errors and produces the data transportation researchers/planners need and use (the questions are formulated in a way that makes the output data “correct” for use in e.g., transport modeling). It is important to aim for both because:

- If minimizing errors is neglected, the data is not representative and potentially full of errors, e.g., not useful for saying anything meaningful about travel behavior in the population one wishes to study.
- If the survey design does not consider the main intended use (transport modeling, transport analysis) and considers the time series, the output data could be considered useless by the planners and modelers and/or break the time series.

Thus, I give the following advice:

- Include persons with survey design knowledge and transportation-specific user knowledge in the NTS survey design planning process.

Having a plan for data collection is essential when it comes to quality. Thus, piloting is necessary before implementing a new strategy. For example, if one considers changing the data collection tool, it is crucial to do pilots and identify what effects that will have on the data material before the change. That way, it is possible to develop strategies and plan how to mediate them when implemented. Moreover, many problems can be avoided if one pilots before the change. This is also important in the NTS context considering the importance of keeping the time-series and how challenging change can be; if one decides to change, it is important to do it from a methodological aware standpoint and with a plan for making the transition as smooth as possible.

Regarding what is “good enough” regarding response rates and representativeness, NTS practitioners should focus on improving their knowledge of NTS non-response in the future. To develop efficient weighting methodologies, we must understand and identify NTS non-response and potential sample selection bias; the bias must be known to assess it properly (Moser and Kalton, 1971). Beyond designing a methodologically aware travel survey (i.e., minimizing the probability of bias in the first place), I have the following advice to improve representativity: 1) evaluate the representativity of samples thoroughly at regular intervals, and 2) analyze the subsamples (e.g., regional add-ons) separately from the national samples. Regarding the first advice, one way to evaluate the representativity is to conduct a non-response analysis. Evaluating representativity and conducting non-response analysis has two purposes:

- It can identify bias in the sample, which can help to identify efficient correction methods and areas of improvement (i.e., where to minimize error).
- If the non-respondents are identified, NTS practitioners can target recruitment strategies towards these and, if necessary, research how to recruit them

efficiently. Furthermore, if selection mechanisms are identified, correcting them is possible.

It would also be fruitful to study the sampling process, especially when stratification is used (e.g., does the stratifying variable provide a more representative sample, or does it create unintended under- or overrepresentations?). Due to the transparency challenges identified in papers I and II, an independent quality controller should conduct non-response analysis and other representativity evaluations.

Regarding the second advice, the reasoning and advice are explained in Table 18. The problem with combining and analyzing the subsamples (e.g., Norwegian NTS regional add-ons) with the primary samples (e.g., Norwegian national samples) is that it can create statistical inference problems (i.e., making conclusions about the population based on the sample (Groves *et al.*, 2009)). In paper I, I discuss the problem of analyzing different samples by presenting the distribution for the regional add-ons versus the national sample and why I separated the results for the entire and national samples when studying NNTS data. Here, I discuss the statistical implications in more detail.

In the Norwegian NTS, the discussed representativity issues (papers I and II) and the choice of analyzing the regional add-ons and national sample together make particular demands on the weighting. Although weights theoretically can be used to correct bias in the sample by improving the distributions, the extensive use of regional add-ons (i.e., disproportional stratified samples) is causing so much bias in the sample distributions (illustrated in Figure 1 in paper I), that the weights are potentially introducing new types of error; the price of improved distributions is that specific individuals get a very high/low influence on the results. This weighting can lead to incorrect estimates (i.e., new error types). Thus, when disproportional stratification is extensively used, it is probably best to study the subsamples separately.

Table 18 NTS representativity strategies

Stratification strategy	Proportional stratification	Disproportional stratification
Random sampling	Simple random sampling (SRS) • One sample • Biased distributions due to non-response	Results in multiple sample(s) of multiple groups (subgroups). • Biased distributions due to non-response and sampling strategy • Sample weighting can become problematic when the samples are combined (analysis) due to varying biases in the samples
Advice		
Weighting advice	One sample weight	To avoid "extreme" weight values on respondents: • One sample weight for the national sample • One sample weight per subsample (e.g., regional add-on)
Analysis advice	Use sample weights to improve representativity in the sample (best practice)	Analyze samples separately (subgroup analysis): • Reduce the probability of adding error to estimates/results through weighting • Increase the utility of responses

To summarize Table 18, when the national sample and subsamples are analyzed together to increase the quantity of data (i.e., increase sample size), it creates problems regarding quality and cost: the quality issues arise because of the sample weights; some respondents get very high weight values, which results in lack of control for the analyst. The cost issue arises because some respondents are not utilized in the analysis due to slight weight values (i.e., their responses are borderline "worthless" because their influence on results is so low). Consequently, combining samples during analysis is inefficient resource management.

5.3.2 Data Collection Tool

Paper II showed how multi-mode solutions are increasingly popular, and CAWI has been introduced in multiple countries. The main advantage of using CAWI appears to be the reduced costs in data collection and reaching some respondents unwilling to participate by phone. However, although the introduction of CAWI mediates some challenges, it also creates new problems. Thus, a question throughout the thesis work has been, "Should we use CAWI"? I have changed my opinion on this multiple times and have landed on that in the NTS context, if used, CAWI should never be used *alone,* and you need correction tools.

Interestingly, Bayart and Bonnel (2022) identified mode-effects in their experiments with similar results as in paper I, but with one exception: the CAWI respondents had a lower trip rate than the CATI and face-to-face interviews. This differs from the results from paper I, where we found a higher trip rate amongst CAWI respondents. Potential explanations for different outcomes in France and Norway could be cultural differences: the French and Norwegian CAWI respondents are perhaps other. If this is the case, it highlights the

importance of understanding national and local differences and how they may affect survey responses. A second potential explanation is that although Norwegian CAWI respondents are more mobile, they appear to be underreporting trips (their trip chains are less complex). Thus, although they seem to be more mobile than CATI respondents, they might still be underreporting trips, as they also appear to do in France, though not to such a large extent. A third potential explanation is that some other aspect of the survey design affects the responses (e.g. CAWI and CATI tool, interviewer effects, the inclusion of face-to-face interviews in France, questionnaire design, different weighting practices, different data cleaning/processing procedures, etc.). Most likely, the answer to the differing results combines the three potential explanations.

Christensen (2013) argues that the advantage of using CAWI is participation amongst highly educated groups and children increases. However, there are two problems with this: firstly, highly educated people are not under-represented in the NNTS, which is fixing a non-existing problem. Increasing their participation rate probably causes increased representativity issues because their over-representation is magnified. Secondly, it is worth asking if mediating the under-representation of the youngest age groups and improving their representativity is worth introducing mode-effects. In paper I, I found signs of mode-effects in the NNTS, and paper II showed that other countries with multi-mode solutions experience the same issues.

An interesting experiment would be to switch the order of CAWI and CATI in the invitation letter in the NNTS: one challenge of CATI in a multi-mode solution is that some respondents use it as a soft-refusal, and the main advantage of CAWI is that it reaches some respondents that would otherwise reject participation, improving the representativity of age (see paper I for further NNTS CATI/CAWI-discussion). Thus, it is more natural to first contact by telephone (CATI), and give the option for CAWI afterward. This is more expensive, but could reduce the share of 0 trip days due to soft-refusal.

Regarding advice for NTS practitioners concerning the use of CAWI, if policymakers and practitioners working with the NNTS survey design say “yes” to continued use of CATI/CAWI-solution, then I give the following CATI/CAWI-specific advice:

- Improve the CAWI tool (interface, usability, etc.) – make it more appealing and understandable for the respondent
- Identify how the CAWI and CATI respondents are different – this demands more research
- Develop practices and correction methodologies to mediate some of the bias caused by multi-mode solutions

- Acknowledge that some things cannot be corrected (this is also supported by Christensen (2013)), and include these limitations in the key reports

A multi-mode solution is necessary if smartphones were to be implemented in the NNTS because, as papers III and IV showed, it is not possible to reach all population segments in a smartphone app solution. Of the combinations available, a smartphone/CATI solution or smartphone/PAPI solution is probably better than a CATI/CAWI/smartphone- or CAWI/smartphone solution. There are two main reasons for this. Firstly, a triple-mode solution introduces so many sources of error that correcting them would be time-consuming and expensive. Secondly, one probably reaches the same group of respondents in a smartphone solution as in a CAWI solution. Thus, using both methods is probably inefficient, although more research is needed on this. A CAWI/smartphone solution would eliminate a lot of respondents, especially those with low trust or knowledge of digital tools (high fear of risk and low technology interest). Such a solution would most likely result in a reduced response rate and underrepresentation of persons who do not use computers or mobile phones extensively (e.g., elders).

5.3.3 Transparency and Key reports

Since the documentation reports (e.g., key reports in the NNTS) are necessary sources of knowledge for those working with NTS data, it is crucial to have clear guidelines for what should be included. Furthermore, the document study revealed that when the organization responsible for data collection changes, it is reflected in the documentation. Understandably, the data collectors present their results positively, because their effects can affect the subsequent tendering process. Still, a lack of transparency can lead to missing documentation on methodology, which can affect future data collections and estimations based on wrong assumptions. To ensure that necessary information is included in public meta-data, those responsible for the tendering process of the NNTS should have clear guidelines for what the key report must consist of so that it includes all necessary information for future data collectors and users of data. An absolute minimum demand of reporting to the key report should be:

- Methodology description
- Response rate
- Share of respondents with 0 trips on the day of reporting
- Trip rates

It could be fruitful to have another institution from the data collector write at least parts of the documentation if possible. When the same institution/organization is responsible for data collection and quality control, it can become challenging to ensure transparency

unless the institutions who finance the NTS demand a “shopping list” of information on methodology description and quality indicators to be included in the documentation. Thus, I give the following advice to improve transparency and to ensure that the methodology is properly documented:

- Formalize and specify reporting requirements in the early stages. If possible, in the data collection tendering process
- Increase the use of independent quality controllers (these can e.g., be used to conduct non-response analysis, external evaluation of survey design implementation, evaluate sample representativity, and suggest improvements)

5.3.4 Pertaining Trust

Ensuring some level of trust between the researcher and respondent/informant has been important in all data collection. I have not studied trust directly in the thesis. However, it was studied indirectly (especially in paper III and IV) by aiming to improve our image and ensure the respondents that sharing their data was safe. For example, being transparent, creating a project website, the logo, guides, and translating was important to show that we respected the participants, were serious about data collection, and at the very least, did not breach the trust. Although we were unable to get high response rates in the TravelVu data collections, we suspect a breach of trust would be devastating for future data collections. Thus, I advise those working on tracking solutions to be careful not to break privacy boundaries, damaging the trust between respondents and institution(s) responsible for data collection.

5.4 Consequences of Plan of the Thesis

In the introduction, I specified some methodological choices regarding the research questions:

- Limited the study of NTS methodology to six European countries
- Focused on studying smartphone apps developed explicitly for collecting travel survey data (not e.g., using tracking data collected for other purposes)
- Focused on survey design choices and how this affects participation

These choices mean that the result from this thesis is not necessarily generalizable to travel surveys beyond the countries studied and other smartphone-based travel survey solutions. Some of the results could be, but this would demand more research. Furthermore, there are potentially some challenges and solutions not identified since I could not study all aspects of the travel survey process. Thus, more research on the travel survey process should be done to develop more advice for practitioners.

5.5 Implications of Limitations

In the methods chapter, I presented some potential methodological challenges. Here, I discuss to what extent they could have affected the results.

In the document study, by also studying peer-reviewed papers, I got multiple sources of information, which reduces the potential of omitting vital information on NTS methodological approaches. I reduced the issue of language barriers with multilingual research assistants. Regarding recruitment in the TravelVU pilots, more interviewers/motivators and/or a pre-gift could have resulted in a higher response rate than we achieved. However, it is unlikely to result in a *high* response rate. Regarding bias in the qualitative interviews, it is possible that some withheld information, but this was probably mediated by the fact that I studied recruitment from multiple angles.

The fact that I have used multiple methods to study both NTSs and respondent behavior mediates the limitations. In addition, I have studied NTSs and respondents using different research approaches, resulting in the same conclusions. As such, I believe the strengths of the other approaches reduced the potential weaknesses.

5.6 Further Research

During the thesis work, some additional knowledge gaps were identified. Here, I discuss suggestions for future research that I wish I had the time and resources to do during my thesis work, but did not, due to costs or time limitations. Lastly, I reflect on a knowledge gap that, if addressed, could solve quite a few of the issues identified in the literature. Hopefully, these reflections can be used to study travel survey methodology in the future.

Firstly, it would have been interesting to interview practitioners (people responsible for NTS survey design and/or quality control) and NTS interviewers to collect experiences from all chains of data collection and get a better picture of day-to-day practice. With a combination of a document study and qualitative interviews, one could aim for methodological triangulation of NTS practice.

Secondly, one issue that needs to be dealt with if one wishes to introduce smartphones is the trip definition, because there are some issues concerning the definitions in the survey process and how it is treated in data processing afterward. This became apparent when working with smartphone app data: e.g., if a person walks between buildings within a campus area and the movement takes 15 minutes, is it a new trip? According to the smartphone app, yes, but according to the NNTS definition of a trip, no. Thus, changing the data collection tool could affect how the respondent and the tool understand the trip,

which can affect the validity if it isn't acknowledged and dealt with appropriately. This is especially important to note and plan for if one chooses a multi-mode solution.

Furthermore, this issue implies that the trip rates aren't stable because it somewhat depends on methodological choices. The effect of survey design does pose some comparability challenges, especially when it comes to smartphone solutions. If the data is not comparable due to varying methodologies but is treated as similar, it threatens the reliability of the data if one studies trends (NTSs).

Thirdly, an exciting result in paper II was that, although the survey design was almost identical (on paper), in Denmark and Norway, Denmark has a much higher reported response rate than Norway. It would be interesting to study this more and perhaps identify why.

Fourthly, more research should be done on trust and what respondents find acceptable in the context of using mobile phone data. Crowdsourcing data from apps not developed to collect travel survey data could be considered an invasion of privacy by some.

Fifthly, the typology can be further developed by identifying the proportion sizes of the reactions, and which population segments are more likely to have certain reactions. This can be done by studying the topic quantitatively. If the proportion of reactions is identified, this can be used to "target" recruitment strategies. It is possible the segment and proportion size changes/develops over time, and varies between cultures and countries, so this is something that should be studied locally and at regular intervals.

Sixth, a lot of the sampling issues discussed in this thesis can perhaps be mediated by using population data from alternative data sources (e.g., register data) because you can study the population directly, thus avoiding the sampling process completely. The potential of population data should be studied further.

Lastly, there seems to be a knowledge gap between practice within survey methodology and travel survey methodology. A large part of the methodological gap is due to a lack of understanding of what is found within other international forefront methodology literature. I don't know how it affects the analyses, only that it does.

6 Conclusion

In this thesis, I have studied NTS methodology using a “troubleshooting” strategy. I have studied the methodology of six NTSs and the potential of a smartphone app solution as a data collection tool. I have aimed to introduce the reader to traditional travel survey methodology, but also show its diversity, and the challenges of changing it. The thesis work has demonstrated that when planning and conducting an NTS (or TS), it is vital to:

- Spend enough resources and time developing a good survey design (this will reduce problems later on). This requires methodological awareness.
- Ensure proper documentation of meta-data and be transparent about challenges.
- Although most people own a smartphone, this does not automatically mean that smartphones can replace traditional survey methods; smartphones will give a new type of data and a particular type of respondent.

There is a catch-22 in choosing a travel survey methodology. On the one hand, it is necessary to use multiple survey modes to get information on all segments. However, the different survey modes provide different versions of the same picture. In the NTS, the aim is to gather information about everybody simultaneously, which is perhaps over-ambitious if one relies on one data collection tool. Combining methods in and of itself is not bad – it improves the knowledge of travel behavior by looking at it from multiple perspectives. However, if one decides to use a multi-mode solution, it is essential to know the limitations and possibilities of the different methods.

The thesis work contributes to the literature on travel survey methodology by continuing a critical discussion on how methodological choices affect the data while also providing information on the consequences of using smartphones as a data collection tool. Focusing on data quality and improving the data collection process is crucial if one wishes to use NTS data in models that demand more detailed data.

To better understand the pros and cons of smartphones, the same way we discuss the pros and cons of telephone interviews, it is necessary to do more research, both pilots and large-scale data collection.

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PART 2

Paper I

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The Decline of the Norwegian National Travel Survey Empire

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Abstract

The purpose of this article is to provide an overview of the trends in the Norwegian National Travel Surveys (NNTS) concerning quality. The analysis is based on a document analysis of NNTS documentation and quantitative analysis of 2016–2019 data. The quality of the NNTS has declined significantly over recent years. Probable causes are non-response due to refusal, underreporting of trips and geographical bias. The current approach does not provide a data that reflects the real travel behavior of the population. In the future, emphasis should be put on increasing the methodological awareness in all phases of the research design.

Keywords: National travel survey; Data quality; Survey design; Document study; Quantitative analysis

1. Introduction

Travel surveys have a key role in transport planning, e.g. for monitoring mobility trends, assessing implications of policy decisions like parking restrictions, tolling etc., and as a foundation for transport models, nationally (Norwegian Ministry of Transport, 2021) and internationally (Stopher et al., 2006). An important concern for transport policy is to ensure a sustainable future and reduce CO_2 emissions locally (Miljøpakken, 2021) and globally (European Commision, 2021). Thus, some policy decisions aim to change the travel behavior of a population. At the same time, there is a wish for an efficient transport sector and for a reduction in CO_2 emissions to not come at the cost of hurting business and industry.

There is an international trend of declining response rates in national travel surveys (Armoogum et al., 2014). Unit non-response, i.e. the inability to gather information about parts of the population due to refusal and/or non-contact, is another increasing problem (Stopher et al., 2006). The decrease in response rate can cause problems with non-response bias because certain subgroups are more and/or less likely to participate in travel surveys, which affects the

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representativeness. For example, people with high mobility rates are less likely to respond in a household travel survey (Richardson, 2000; Stopher et al., 2006).

It might be tempting to replace current travel survey approaches with new technology in the hopes of overcoming these problems. Several countries now have initiatives for trialling tracking of travelers to collect similar types of data. These show promising results, but also introduce new problems, among them privacy issues and even lower participation rates (Svaboe et al., 2021).

In this paper, we aim to answer the following research questions about the Norwegian National Travel Survey (NNTS):

1. What has been the development in quality?
2. What are the main challenges?
3. What should we do in the future?

Our approach is to study documentation reports of the current and older methodology to identify fruitful solutions for the future. A document analysis has been performed of the NNTS in the period between 1984 and 2020. We have also analyzed some of the data from the NNTS from 2016 to 2019.

2. Background

In order to correctly scale transport systems, understanding how people use it is key. Two main approaches exist: digital tracking without consent or self-reporting of behavior. The digital tracking approach is effective. However, it raises several ethical and regulatory (e.g. the GDPR) concerns. Therefore, travel surveys (i.e. self-reporting) are most common in Europe.

The data collection methods in travel surveys are similar between countries. The main difference is that some countries conduct household travel surveys, such as England (Department for Transport, 2020) and Germany (Eggs et al., 2018), and others conduct personal travel surveys, such as Norway (Opinion AS, 2021) and Sweden (Trafikanalys, 2018a). Response rates are declining for all. There are initiatives studying the potential of smartphone tracking as a supplement or replacement for traditional self-reporting (Trafikanalys, 2018a, 2018b; Vågane et al., 2013). However, no country has taken the full step of changing the method in their NTS, and self-reporting using traditional surveys is still the standard.

Internationally, response rates are falling in national travel surveys. The Swedish Transport Administration disregarded the 2011-2014 Swedish NTS due to the low response rate and other representativity issues (Silvano et al., 2020). Representativity issues have led to some countries considering alternative collection methods. Transport Analysis, which is responsible for official transport statistics in Sweden, has researched new methods to improve the response rate and data quality, including testing new technologies. In England, the response rates were quite stable until 2015 at around 60 percent (NatCen Social Research, 2019). The response rate fell to 58 percent in 2016 and 53 percent in 2018. The main reason is an increase in refusal rates (NatCen Social Research, 2019). The English Department for Transport implemented measures to stop this trend, including developing alternatives to the paper diary, studying incentives, changing the advance letter, methodological changes to improve data quality and establishing a panel of respondents for follow-up research (Department for Transport, 2019).

The main task a survey designer has when it comes to quality is to minimize errors in the survey statistics (Groves et al., 2009). Sample surveys, which most NTSs are, rely on two main sources of inference that can affect quality (Groves et al., 2009): 1) inference from the questions to the constructs, and 2) inference from the sample statistics to the statistics of the population in question. Unfortunately, all steps in the survey design and data collection process are subject to imperfections, and these cause statistical errors. Currently, there are no international standardized guidelines or checklist for measuring quality in national travel surveys. A common assumption among analysists is that a high percentage of people reporting non-mobility on the day of reporting indicate poor technique in the survey (Stopher et al., 2006).

The response rate is the most frequently used measure of quality in surveys. A low response rate is not necessarily problematic if non-responders and responders don't travel systematically differently. The problem arises if non-response can be connected to the theme of the survey. For example, if people who travel much decline to participate in a travel survey because it takes too long to report their trips, this creates bias in the sample, jeopardizing representativity. Non-response is higher in urban than in rural areas (Paskota, 2006). If there exists underlying

exclusion mechanisms that affect the responses, this cannot be fixed by weights (because creating weights for correction purposes requires that we know the true behavior of the population). The risk of bias in the sample due to non-response increases with a low response rate so a high response rate is desirable. A high response rate reduces the probability of having non-response bias (Stopher et al., 2006).

Representativity in a travel survey is based on demographics (Armoogum et al., 2018). Geographical representativity is particularly crucial in travel surveys. Further, studies (Ben-Akiva and Lerman, 1985; Domencich and McFadden, 1975) have shown how sociodemographic and socioeconomic characteristics (age, gender, education, professional status etc.) have an effect on choices in travel behavior. Representativity is ensured in two phases: 1) the recruitment phase and 2) the weighting phase. According to Armoogum et al. (2018), the main challenges of representativity in travel surveys are connected to the sampling frame, total non-response, and measurement errors.

Training and supervision of interviewers is essential if they are used in data collection (Groves et al., 2009). It is important that the field manuals are well-constructed, especially if the surveys are complex. These need to anticipate potential problems so that the interviewer is prepared. Further, supervisors are necessary to train and give confidence to inexperienced interviewers. There are many techniques for personal interviewing, including how to make the respondent feel comfortable and maximizing response. According to Groves et al. (2009, p. 132), the training should emphasize the interviewer's ability to "read fluently, speak clearly, and be able to ad lib answers to interviewee's questions".

There are multiple ways to collect travel survey data. Face-to-face interviews is the most traditional way to conduct a survey (Paskota, 2006). Here, the interviewer visits the respondents and asks them about their travel behavior. The main advantage of face-to-face interviews is that they are flexible, the interviewer can motivate the respondent and it is easier to clear up misunderstandings (Ringdal, 2007). The disadvantages are that it is costly, requires local interviewers, is time-consuming and the probability of interviewer effects are high (de Vaus, 2014). The personal interviews can be done either by paper-and-pencil (PAPI) or be computer-assisted personal interviews (CAPI).

Computer-assisted telephone interviewing (CATI) is a popular option. Its main advantages are that it can reduce response time, reach a higher geographical area and reduce costs (de Vaus, 2014; Ringdal, 2007). The disadvantages are that it is easier for the respondent to decline participation, and it works best for shorter questionnaires.

In computer assisted-web interviewing (CAWI), the respondent completes a questionnaire online. This technique can help reach a geographically diverse population and provide the respondents more flexibility (Ringdal, 2007). It is also cheaper than the aforementioned options (Groves et al., 2009). However, the main disadvantages are that non-response is higher when using this method (de Vaus, 2014) and the risk of misunderstandings is increased.

One way to address the issue of reaching certain groups is to use multiple administration methods at the same time. When combining methods, it is possible to utilize their strengths, while reducing their drawbacks (Paskota, 2006). There is, however, a risk of mode effects (de Vaus, 2014). Mode effects occur when the method affects the way people respond to the questions. This can result in issues with identifying whether behavior differences are group-specific (e.g. age, gender) or method-specific.

With a high penetration rate of smartphones worldwide with built-in GPS, interest in smartphone data for studying travel behavior has increased. Advantages of tracking technology for travel behavior studies is that it does not rely on memory (Deng and Ji, 2010), and enables a higher level of detail (Hong et al., 2021). There are, however, privacy and representativity issues related to this type of data (Romanillos et al., 2016).

It can be challenging to navigate different NTSs because the method varies between countries, reports are written in different languages and sometimes the documentation of methodology is lacking. Internationally, it appears that national travel surveys are in a state of quality crisis due to representativity issues, mainly due to non-response. Little research seems to be carried out, however, to understand these challenges properly. In this paper, we map their extent, root causes, and consequences, highlighting the problematic trends and status quo with Norway as a case.

3. Method

3.1. Document analysis

The document study includes letters, reports, formal evaluations, e-mails and data sets connected to the NNTS in the time period 1984–2021. The documents have been collected over a period of 6 years (2016–2022). The following

information was collected: 1) Sampling method, 2) Data collection method description, 3) Recruitment method description and invitation material, 4) Response rates and representativity discussion and 5) Interview duration (time, number of questions).

Table 1 Selection of documents describing and reviewing survey methodology in NNTS 1984–2021

Name	Document type
"Travel behaviour in Norway" (Stangeby, 1987)	Key report 1984/1985
"Travel behaviour in Norway" (Vibe, 1993)	Key report 1991/1992
"Travel behaviour in Norway 1998" (Stangeby et al., 1999)	Key report 1997/1998
"Den nasjonale reisevaneundersøkelsen 2001 – nøkkelrapport" (Denstadli and Hjorthol, 2002)	Key report 2001
"2005 Norwegian National Travel Survey – key results" (Denstadli et al., 2006)	Key report 2005
"2009 Norwegian National Travel Survey - key results" (Vågane et al., 2011)	Key report 2009
"2013/2014 National travel survey - key results" (Hjorthol et al., 2014)	Key report 2013/2014
"The Norwegian national travel survey 2018/2018 – key results" (Grue et al., 2021)	Key report 2018/2019
"Nasjonal reisevaneundersøkelse (RVU) Nøkkeltallsrapport" (Opinion AS, 2021)	Key report 2020
"Reisevaneundersøkelse I Norge 1984-1985: Sluttrapport fra planleggingen av undersøkelsen" (Bolkesjø and Solheim, 1984)	Report on the planning of the first NNTS
"Metoder for framtidig RVU" (Christiansen, 2013)	DTU's evaluation of the NNTS and new technology
"Metoder för framtida resvaneundersökingar. Bidrag baserat på erfarenheter från Sverige" (Nilsson and Adell, 2013)	Trivector's evaluation of the NNTS and new technology
"Metoder for framtidige reisevaneundersøkelser" (Meland and Nordtømme, 2013)	Sintef's evaluation of the NNTS and new technology
"Metoder for framtidige reisevaneundersøkelser – TØIs vurderinger" (Vågane et al., 2013)	TØI's evaluation of the NNTS and new technology
"Methodology of travel behavior research. A discussion of methodological problems associated with national travel behaviour surveys" (Stangeby, 2000)	A discussion of methods and challenges in NTSs
"Passenger Transport in Norway. The Present Situation, Changes in the Last Decades and Factors Influencing Transport Mode" (Stangeby et al., 1996)	Document analysis of person transport in Norway
"National travel survey – interview or web-based" (Christiansen et al., 2015)	A comparison of the responses in the NNTS using CATI and CAWI

Most of the reports can be found on the home page of the National Public Roads Administration (NPRA), or the Institute of Transport Economics (TØI). To filter out (potentially) irrelevant NNTS reports, only documents with a description and discussion of methodology in the NNTS were included. For example, published tables and numbers without a description of the data collection process and response rate discussion is not considered. The list of relevant public documentation of the NNTS is presented in Table 1. All of the reports except Bolkesjø and Solheim (1984) are open-access.

3.2. NNTS datasets for 2016-2019

To study the compositions of the samples and differences between CATI and CAWI respondents, NNTS data sets for the period 2016–2019 were analyzed. The data material consists of two data sets: 2016–2018 and 2019. The data set used in the key report for 2018/2019 is a constructed year based on data from 2018 and 2019. Unfortunately,

neither this data set nor the necessary documentation to reconstruct it is available. Comparing our own estimations of travel behavior with key reports from prior years could be affected by different analysis choices. Thus, the analysis comparisons is limited to the data sets available. We discuss the representativity by comparing descriptive statistics on level of education based on data from 2016-2019. This is then compared with population information collected from Statistics Norway (SSB) database (Statistics Norway, n.d.). We have also done some estimations on the average trip frequency and share of respondents with 0 trips on the day of reporting for the national sample and entire sample. We have used the sample weights included in the data set for some of the analysis (it is specified when used).

3.3. Limitations

The documentation quality for each collection period varies greatly. Little recruitment material is publicly available from the first NNTS collections. For 2016/2017 there is no documentation at all. The documentation improved significantly after the third NNTS, probably because it was officially decided in 1995/1996 that the NNTS should be conducted every four years (Denstadli and Hjorthol, 2002). As of yet, there are no published response rates for 2020. Thus, it is possible that some challenges have not been documented and therefore are not mentioned in this paper. Absence of methodological documentation can have a significant negative effect on the reliability of future NNTSs if key people leave the project. Since we neither have the 2018/2019 key report dataset nor the codebook for the 2016-2018 and 2019 datasets, it is challenging to compare travel behavior further back than 2016. We study the trip frequency and immobility at a superficial level.

4. Results

The NNTS is personal and has been conducted since 1984, with new collection rounds approximately every four years. The first survey was undertaken face-to-face. After that, telephone interviews were used. Several local travel surveys have been carried out in parallel up until 2009, with approximately the same design and methods. Geographical add-on samples were discussed prior to the first NNTS (Bolkesjø and Solheim, 1984), were introduced in the third (Stangeby et al., 1999), and have grown in use, inducing an increase in sample size (Grue et al., 2021).

Three major changes were made in 2016 and these are reflected in data and documentation. Firstly, it was decided that the data collection was to be done continuously until 2020. Secondly, a web-based solution was made available to respondents. The sample was sent a letter informing them that they had been chosen to participate, with a link included. Those that didn't respond got called by an interviewer and were asked to complete by telephone (CATI). Thirdly, the NNTS was put out to tender, which caused structural changes. Until 2016, the Institute of Transport Economics (TØI) was responsible for data collection. Between fall of 2016 and April 2020, Epinion was responsible for data collection. In 2020, Epinion filed for bankruptcy. Opinion took over and has been responsible for data collection since April 2020. Opinion decided to prioritize CATI for the rest of 2020, the argument being that it would allow data collection to commence sooner (Opinion AS, 2021). In 2021 the CAWI/CATI-combination continued. The NPRA have recently initiated a technical pilot study into smartphone tracking.

4.1. The sample

The NNTS response rate has declined steadily, falling from 77 percent in 1984/1985 to 16 percent in 2018/2019 (2020 not yet published). There was a relatively sharp decline between 2001 and 2005. This was commented on in several of the reports, but it was not until the 2013/2014 report that it was addressed as an acute problem. There is one exception in the trend. Between 1998 and 2001 the response rate increased from 51 to 64 percent. 2001 was the first year with invitation letters, and much care was given to recruiting hard-to-reach age-groups. Persons 65 and older got

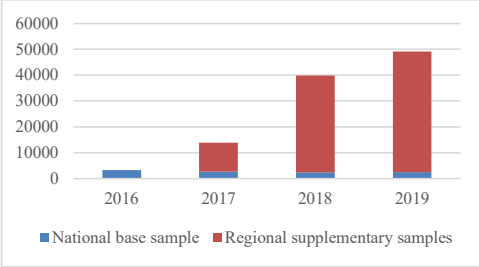

Figure 1 Sample composition (2016-2019)

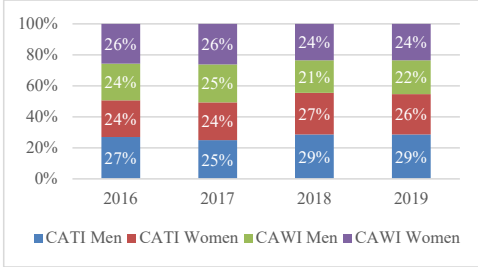

Figure 2 Administration method distribution in sample (2016-2019)

tailored information letters, and persons in the age group 20-29 were contacted through their parents or by mobile phone if initial contact was unsuccessful (Denstadli and Hjorthol, 2002). In 2004, the response rate decreased again. Recruitment strategy discussions has gotten less space in the key reports since then, but the level of detail varies from year to year. Another trend identified in the key reports, is that the differences in geographic representativity have increased. The proportion between the national base sample and regional supplementary samples has changed massively in the period 2001–2018/2019 (Grue et al., 2021). Today, the national sample constitutes a minority of the data material, while regional samples dominate (Figure 1). Figure 2 illustrates the CATI/CAWI-gender distribution of respondents. Traditionally, people in their 20s and elders are underrepresented (Denstadli et al., 2006). In the CATI/CAWI-distribution for different age groups for the national samples 2016-2019, there were age differences. For example, in 2017-2019, age group 13-17 preferred CAWI, and in 2016-2019, people in their 20s, early 30s and 75 and older preferred CATI. Grue et al. (2021) had similar distributions for 2018/2019. In recent key reports, the data is weighted for geography, age, gender and day of reporting. The socioeconomic resources of the respondents are neither weighted for nor discussed. Comparing NNTS samples with SSB data (Table 2), results indicate an underrepresentation of low education groups and overrepresentation of high education groups in the NNTS. NNTS compositions significantly differ ($p<0,001$) from SSB distributions.

Table 2 Level of education by gender, 16 years and older 2016-2019 (percent), All=entire sample, NS=national sample, SSB=Statistics Norway

Year	2016			2017			2018			2019		
	All	NS	SSB	All	NS	SSB	All	NS	SSB	All	NS	SSB
Men												
Basic school level	8.6	8.6	26.9	8.4	7.2	26.7	8.8	9.8	26.4	9.7	10.0	26.0
Upper secondary education (incl. tertiary vocational education)	42.0	42.0	43.9	36.3	40.4	43.7	37.5	39.7	43.5	40.2	42.2	43.6
Higher education (short)	27.8	27.8	19.0	30.1	29.5	19.2	29.3	29.1	19.5	28.3	27.8	19.6
Higher education (long)	21.7	21.7	10.2	25.2	22.9	10.4	24.3	21.4	10.6	21.8	19.9	10.7
Women												
Basic school level	8.8	8.8	26.2	9.4	9.2	25.7	8.9	11.0	25.2	10.3	9.6	24.6
Upper secondary education (incl. tertiary vocational education)	35.8	35.8	37.3	34.4	33.9	36.9	33.1	32.2	36.6	33.3	33.1	36.3
Higher education (short)	35.2	35.2	27.8	33.2	34.0	28.3	34.3	34.8	28.7	33.6	34.3	29.1
Higher education (long)	20.2	20.2	8.7	23.0	22.9	9.1	23.7	21.9	9.5	22.8	23.0	9.9

4.2. Change in trip frequency

The trip frequency declined (12%) between key reports for 2013/2014 and 2018/2019 (Grue et al., 2021). At the same time, the number of trip chains has remained quite stable. The average number of trips per person per day has consistently been higher than 3 between 1984 and 2014. In 2018/2019, the average trip frequency per person per day

was 2.82. According to Grue et al. (2021), the reduction is due to change of method and not a change of travel behaviour. Since 2016, respondents can choose between CAWI and CATI. Grue et al. (2021) found a reduction in short trips, and that the average number of trip chains per person per day was higher for CAWIs, although the chains were less complex. Reasons for higher trip rates in CAWI compared to CATI could be higher mobility rates among CAWI respondents and probably more soft refusals in CATI. In the 2018/2019 data material, those who reported their trips by web and those who reported by telephone have different travel behaviour (Grue et al., 2021). There are also signs of responders and non-responders travelling differently. In particular, short trips with walking as mode of transportation and trips where car is the main mode of transportation (public transport users are overrepresented in the data material) appear to be "missing" since the survey design was changed (Grue et al., 2021). There are fewer short trips (short stops not registered), and this trend is stronger in the CAWIs than the CATIs (Grue et al., 2021). There is also an increase in respondents with no trips, and the increase is stronger for the CATIs than the CAWIs (Grue et al., 2021). We estimated average trip rate (Table 3) and share of respondents with 0 trips on the day of reporting (Table 4). There is a statistically significant ($p<0,05$) difference in trip rates between CATI and CAWI respondents, and a statistically significant ($p<0,05$) relationship between share of respondents with 0 trips and survey mode (which can affect trip rate estimations), for all years and samples.

Table 3 Trips per person, entire sample (All) and national sample (NS) 2016-2019, mean and SE

Sample	All				NS			
	Weighted		Unweighted		Weighted		Unweighted	
Year	CATI	CAWI	CATI	CAWI	CATI	CAWI	CATI	CAWI
2016			2,62 (,05)	2,93 (,05)			2,62 (,05)	2,93 (,05)
2017			2,73 (,02)	3,09 (,02)			2,64 (,05)	3,00 (,06)
2018			2,78 (,01)	3,07 (,02)			2,65 (,05)	2,95 (,06)
2019	2,66 (,02)	2,96 (,02)	2,69 (,01)	3,00 (,01)	2,64 (,07)	2,99 (,09)	2,70 (,05)	3,07 (,06)

Table 4 Share of respondents with 0 trips, entire sample (All) and national sample (NS) 2016-2019, percent

Sample	All				NS			
	Weighted		Unweighted		Weighted		Unweighted	
Year	CATI	CAWI	CATI	CAWI	CATI	CAWI	CATI	CAWI
2016			19.2 %	11.0 %			19.2 %	11.0 %
2017			16.8 %	9.3 %			17.8 %	10.3 %
2018			14.4 %	11.1 %			15.3 %	12.1 %
2019	16.5 %	11.7 %	15.9 %	11.2 %	17.0 %	12.4 %	15.5 %	10.7 %
2018/2019 (Grue et al., 2021)	16.1 %	12.2 %	15.0 %	12.5 %				

4.3. Respondent burden

The best estimate available for response burden in the NNTS is the average response time (minutes). This has not been reported for every collection round, but the questionnaire has and, in some years, also the invitation letter. Given that the number of questions included has not been significantly reduced, the average response time has always been at least 20 minutes. The invitation letter for 2021 and 2022 suggested an average completion time of 20-40 minutes.

4.4. Historical overview of trends and changes in data collection methods

Table 5 gives an overview of the trends in the NNTS from 1984 to 2020. It includes information about structural changes that could influence the data material, the response rate, number of respondents, average trip frequency per respondent per day, and information about sampling and data collection method. It illustrates how the methodology has changed with implementation of new collection technology, how the response rate has declined, while at the same time the sample has grown.

Table 5 Historical overview of the Norwegian National Travel Survey 1984–2020 (Bolkesjø and Solheim, 1984; Denstadli et al., 2006; Denstadli and Hjorthol, 2002; Grue et al., 2021; Hjorthol et al., 2014; Opinion AS, 2021; Stangeby, 1987; Stangeby et al., 1999; Vågane et al., 2011; Vibe, 1993)

Year	Response rate	Respondents	Trips	Measures and policy changes causing structural changes	Data collection method	Age	Sampling method	Average response time (min)
1984/ 1985	77 %	4320	3,2	First national travel survey	Face-to-face PAPI Information brochure mailed to sample	13–74	Persons from SSB's personal register.	50
1991/ 1992	67.5 %	6000	3,12	Data collection method change	CATI	13 +	Combination of person and phone register. Interviews the person with the most recent birthday	Not available
1997/ 1998	51 %	8838	3,14	The first NNTS after decision to conduct NTS every four years Regional add-ons introduced	CATI	13 +	Household phone numbers from Telenor database. Interviews the person with the most recent birthday	20
2001	64.2 %	20 751	3,03	Increased sample Improved recruitment material	Invitation letter w/diary + CATI	13 +	National Population Register	24
2005	47.9 %	17 514	3,33	Oversampling of age groups 20-29 and 65+	Invitation letter w/diary, motivational conversation and material check + CATI.	13 +	National Population Register	24,5
2009	45.6 %	28 922	3,30	No documented structural changes	Invitation letter w/diary, motivation conversation and material check + CATI.	13 +	National Population Register	21
2013/ 2014	20 %	61 400	3,22	Evaluation of the NNTS and new technology by DTU, Trivector, Sintef and TØI	Invitation letter w/diary, motivation conversation and material check + CATI	13 +	National Population Register	21
2016/ 2017	Not available	17 125		CAWI introduced. Continuous data collection. NNTS put out to tender	Invitation letter to CAWI. CATI if the respondent does not respond.	13 +	National Population Register	Min 20
2018/ 2019	16 %	88 548	2,82	No documented structural changes	Invitation letter to CAWI. CATI if the respondent does not respond.	13 +	National Population Register	Min 20
2020	Not available	38 448	2,35	Smartphone tracking methods in development	Invitation letter to CAWI. CATI if the respondent does not respond. Only CATI after data collector changed	13 +	National Population Register, Data Factory AS	Min 20

5. Discussion

5.1. Development in data quality

There are signs of geographical, socioeconomic and sociodemographic bias in the samples, the non-response is high and increasing, the response time is long, there is an under-reporting of trips, and there are negative side-effects of using multiple data collection methods at the same time (those who were called in the 2018/2019 data set had more "no trip days" on the day of reporting, indicating that at least some of them only said this to reduce the answer time or misunderstood the questions). All of these issues challenge the quality of the data material.

NTSs are designed to study long-term developments and trends. The calculated trip frequency fell below 3 trips per person per day at the same time as the major structural changes in the NNTS were implemented in 2016. However, a sudden drop in trip frequency in the population seems unlikely. The analysis reveals that the "missing" trips in the newer data are mainly shorter trips, and that the CAWI-respondents and CATI-respondents travel differently. This indicates that there is an underreporting of trips, as opposed to a drastic change in the population's travel behavior. It is possible that those who answered the online questionnaire did not consider the short trips as trips the same way that the data collectors do. For example, a short stop to buy milk or deliver a book at the library on the way home from work might not be considered a trip by all respondents.

A possible explanation for the increased number of no-trip days and a decreasing average trip frequency is that it might be easier to recruit those with a low number of trips in a travel survey. The low trip frequency from the 2020 data could be explained by changes in travel behavior due to lockdown after COVID-19 policies were implemented.

A skewed selection due to non-response makes the weighting of the data demanding. Even though some of the issues mentioned could be mediated through weights (such as an overrepresentation of highly educated people), the potential errors, in combination with a small national sample, multiple regional supplementary samples and overrepresentation of public transport users, make weight construction difficult. In order to make decent weights, it is necessary to have a certain knowledge about the population in addition to knowing that the sample *can* represent the population. With a sample consisting of mostly regional samples, and multiple signs of bias, it is problematic to do this, because there are so many potential sources of error. The situation in Norway is serious. We know that there are challenges in other countries as well, but not how extensive they are.

5.2. Main challenges

To sum up, the following challenges (not an exhaustive list) needs to be dealt with:

- Declining response rates
- Duration of survey is too long
- Biased geographic sampling
- Declining trip frequency
- Increased share of non-travel days
- Over-/underrepresentation of certain socioeconomic/sociodemographic groups

Even though there are multiple challenges in the NNTS (that are not necessarily independent of each other), we argue that the main ones are: 1) non-response and 2) underreporting of trips. These are the most acute, because they show two major weaknesses: 1) the data material is not representative of the population and 2) the respondents do not understand the trip definition being used, causing validity issues. Overall, one of two choices needs to be made: either a complete overhaul of the survey methodology (for example create a new questionnaire from scratch or change methodology), or try to fix the current design (e.g. reduce the number of questions).

5.3. Future solutions

A lot of time and money can be saved if representativity is ensured in the recruitment process. This can also reduce the need to add samples due to non-response. Adding regional supplementary samples or increasing sample size does not fix non-response. It does, however, increase sources for error. Thus, in the future, a larger effort should be made in targeting recruitment and reducing respondent burden. This has a proven effect, documented in the NNTS in 2001.

Research (Goyder, 1985; Groves et al., 2009; Heberlein and Baumgartner, 1978) shows that the complexity of self-administered instruments and perceived length of time can affect respondent cooperation. The response time in the NNTS is at least 20 minutes, which can result in a perceived high burden to respondents believing 20 minutes to be too long. This can result in underreporting of trips and non-response. Thus, in the future, NNTS survey designers should try to reduce the number of questions included in the questionnaire. Given a CATI-/CAWI-based solution, a short-term measure could be to limit the questionnaire to 10–15 minutes and improve the field manual. For example, one can omit questions that one can look up the answers to in public registers and maps (such as car ownership and closest bus stop to home address) and instead collect this information after the interview. Reducing the questionnaire length would also reduce potential exhaustion for the interviewers, making it less likely that misunderstandings occur. Improving the field manual could reduce the probability of respondents misunderstanding the trip definition. A more long-term solution would be to perform a complete review of the survey design because there is a high probability of trickle-down effects of problematic design in the early stages.

As of writing, a smartphone tracking solution is in the works in Norway. Even though big data and register data have great potential for analysis, switching methods is not a quick fix. There are drawbacks with the use of alternative data sources such as representativity issues (not everyone will participate in a smartphone TS), validity issues (trips are registered differently), limitation of use with big data in traditional transport models, and privacy issues. Taking care of these issues might demand just as much (or more) resources as improving the current survey design.

Reducing the questionnaire and using only CATI could mediate the problem of survey mode effects and perhaps increase response rates. With trained interviewers, it is less likely that the respondent misunderstands the trip definition, thus reducing underreporting due to confusion. Interviewers can also motivate respondents to participate, increasing the response rates. Using a CATI solution also ensures the continuation of the time-series. One of the main arguments for not drastically changing the NNTS questionnaire and switching to alternative methods has been the goal of continuing the time-series. However, the time-series was for all intents and purposes disrupted in 2016 with the major structural changes and introduction of CAWI. Furthermore, the quality of the 2013/2014 data is questionable due to representativity issues and bias. Thus, one can argue that the time-series "peaked" in 2009.

On one hand, the "end of the time-series" could make it easier to argue for completely rebooting the NNTS. On the other hand, the documentation shows that the issue with quality is more complex than choice of data collection method. It also shows that targeted recruitment is effective. Therefore, using experiences from the past, NNTS survey designers could implement measures to improve data quality without using smartphone tracking. A history-based approach to improving quality would result in less variables due to a shorter questionnaire. However, this can be mediated by using public records to supplement the data. Further, we argue that it is better to have a less detailed data set of higher quality, than a high-detail data set of lower quality.

If multi-mode solutions have come to stay in the NNTS, it is necessary to resolve the issue of data comparability over time and between modes (see Bayart and Bonnel (2022) for a further discussion on mediating mode effects in travel survey data).

6. Conclusion

The documentation made available indicates a systematic bias in the data that cannot be fixed with weights, because sample selection bias cannot be corrected using traditional methods. The following measures has been made to change and/or evaluate the decline in quality by NNTS survey designers: the sample has increased, there was an external evaluation in 2014, improved recruitment material was tested in 2001, and CAWI was introduced in 2016. Of the efforts made, the only one that showed a direct effect on the response rate was the improved recruitment material.

In the future, emphasis should be made on the recruitment phase to avoid problems with representativity later on. One way to do this could be to reduce the respondent burden by reducing the questionnaire length. Further, the interviewers need the necessary training to both motivate the respondent to report all their trips and provide the respondent with an understandable description of what a trip is.

In order to increase the quality of the NNTS, the survey design needs improving. Further, everyone involved in the data collection process must have the necessary skills to realize the design, because bad decisions and mistakes in the early phases will trickle down later. This requires methodological awareness of everyone involved in planning, data collection and data processing of the NNTS. The next step in order to evaluate the NNTS is to study mode effects

more in-depth, for example by comparing travel behavior between subgroups of the sample weighted for (gender, age and geography). Furthermore, it is necessary to study the effect of chosen sampling strategy in NTSs from an urban-rural perspective (it is mainly the larger cities that buys add-ons).

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Paper II

A Comparative Study of National Travel Surveys in Six European Countries

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This paper is submitted for publication and is therefore not included.

Paper III

Recruitment strategies in app-based travel surveys: Methodological explorations

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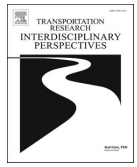

Understanding skepticism of smartphones in travel behavior research: A qualitative approach

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ABSTRACT

Travel behavior research is increasingly reliant on data collected from smartphones. However, recruitment is challenging in app-based travel surveys, which can cause data quality issues, such as non-response bias and erroneous trip rates. We aim to explain why it is challenging to get people to participate. This article is based on an analysis of transcriptions and notes from two qualitative studies, using risk, diffusion, and privacy theories. We have identified six themes in the data material and have developed a typology of reactions to smartphone apps. Perceived risk and digital technology interest may explain reactions to the use of smartphone tracking technology in travel behavior research. In the future, this typology can be used to improve our understanding of non-response in smartphone travel surveys and mitigate these.

Introduction

Travel behavior has been studied for decades, traditionally using travel surveys (TS) (Wang et al., 2018). It is important to choose the right tool for data collection because the data quality is affected by how satisfied the respondent is with the travel survey instrument (Roddis et al., 2019). Smartphone apps are a promising new platform for collecting travel survey data, with the potential to provide higher precision (Hong et al., 2021). Traditional travel surveys ask respondents to recall travel behavior from memory. On the other hand, smartphone apps, with tracking technology, remove this limitation. There are three main ways to utilize smartphones in travel behavior research: (1) analysis of cell tower data (Lee and Sener, 2020; Saxton, 2018), (2) using designated travel survey apps, e.g. Atlas II (Safi et al., 2015), TravelVu (Hubrich et al., 2020), MoveSmarter (Geurs et al., 2015), or MEILI (Prelipcean et al., 2018), and (3) extract data from other tracking apps. One app in the third category that has made its user data available for purchase and is popular among travel behavior researchers is *Strava* (Griffin and Jiao, 2015; Jestico et al., 2016; Raturi et al., 2021). Crowdsourcing data is gaining popularity because it is a relatively efficient, low-cost way to collect large amounts of data. If the identity of a smartphone user can be determined, travel data collected from the phone could be combined with external registers, increasing the potential for further data analysis. Using such aggregated data in travel behavior research, however, raises issues of privacy (Nunan and Di Domenico, 2017; Rubinstein, 2013) and representativity (Livingston et al., 2021; Romanillos et al., 2016).

It has been challenging to recruit respondents in travel surveys with smartphone apps (Saxton, 2018; Svaboe et al., 2021). The success of such solutions is determined by the extent to which people *want* to use them, and whether they do so correctly. Some research on the acceptance of smartphone data use by researchers exists, but it is not very extensive. Moreover, the studies that do exist show that many smartphone users are skeptical about strangers analyzing their data (Julsrud and Krogstad, 2018). Thus, if this type of data is to be used in research and planning, the process must adhere to the norms and expectations of the population one wishes to study. A breach of trust can negatively affect the public perception of companies and public institutions involved. Still, smartphone-based travel survey pilots (Cottrill et al., 2013; Svaboe et al., 2021) have shown that some respondents continue data logging after the requested data collection period, indicating that there is an interest in having a record of travel behavior. Therefore, the current paper aims to identify recruitment challenges, by studying the topic qualitatively. Travel behavior researchers are more likely to identify the best data collection tool in the survey design phase by identifying the challenges. The following research question is asked: *Why is recruitment challenging in app-based travel surveys?* To answer this, we develop a typology of reactions to new technology, using smartphone

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apps as a use-case.

Using theory on risk (Beck, 2009, 1999, 1992) diffusion (Rogers, 2002, 1995), and privacy (Francis, 2008; Rachels, 1975), we have analyzed transcriptions from focus groups and notes from personal interviews, and developed a typology of reactions to smartphone apps. We use the typology to answer the research question. We neither aim to condone nor glorify technology that tracks movement and the use of it in travel behavior research. Instead, we aim to improve the knowledge of human reactions to new digital tools. Insights will allow researchers to better design travel survey methodologies that respondents are happy to use, potentially reducing non-response. Such data collection tools would be valuable in transport planning, provided that a representative part of the population uses them and are willing to share their data.

Background

In this chapter, we present relevant research and results from studies on how respondents react to the use of tracking technology, i.e., research on the *respondent perspective* on smartphone tracking. Then, the theoretical framework for the analysis is presented.

Reactions to smartphones in travel behavior research

Julsrud and Krogstad (2018) studied public acceptance of using mobile phone tracking data in Oslo and Tallinn, citing significant skepticism amongst respondents in both cities, towards institutions or governments collecting and analyzing such data. More than half of the respondents in both cities worried their tracking data would be mishandled or get astray (Julsrud and Krogstad, 2018). Further, no immediate connection was found between risk perception and the extent to which respondents used or relied on their smartphones; the most active social media users and users of navigation services were just as worried about their privacy being violated as those who did not use such applications. The authors did, however, find that the acceptance of using tracking data depended on the purpose. They were skeptical towards business development, while prevention of terror and crime was the most accepted. About half of the respondents said it would be acceptable to use tracking data to improve the transport systems.

There have been attempts of implementing tracking solutions in large-scale travel surveys, with mixed results. In France, GPS and smartphones were used in travel survey pilots in connection with the national travel survey. According to Richard and Rabaud (2018), smartphone surveys have recruitment, data collection, and processing challenges. During a GPS-based travel survey in Adelaide, Australia, focus group interviews were conducted (Swann and Stopher, 2008). Practical challenges were identified (e.g., low battery life, "clunky" device design, interface problems), but the authors argued that the GPS devices reduce respondent burden. Furthermore, some participants wanted to contribute and receive more from the project (e.g. provide feedback about data collection and context for their data). In Sweden, pilots with apps and cell tower data were conducted during the project *New solutions for future travel surveys* (Saxton, 2018). The project group concluded that even though the technology is promising, response rates are too low for use in national travel surveys. The Netherlands uses smartphones for an ongoing mobility panel (Thomas et al., 2018). In the USA, there are examples of smartphone household travel surveys (Flake et al., 2017; Lynch et al., 2019). In Singapore, a smartphone pilot was conducted with a subsample (1000 persons) in the Singaporean Household Interview Travel Survey (Cottrill et al., 2013). The authors concluded that recruitment was more challenging, and completion rates were lower in the smartphone sample. Furthermore, the travel behavior and demographics were fundamentally different between smartphone participants and online/call center participants.

Many popular apps exist that track movement using similar technology as travel survey apps. Garrett et al. (2021) studied the public acceptability of smartphone tracking and COVID-19 tracking apps in Australia. They identified that the main reasons for *not* using a COVID-19 tracking app were data security (privacy concerns, concerns about normalizing tracking, lacking trust in the government) and functionality (e.g., battery drain). Compared to users, non-users were to a larger extent misinformed about the technology. At the same time, more than 50 percent of respondents reported government policy as the main reason for having downloaded the app. VonHoltz et al. (2015) studied the use of smartphone health apps, finding that among app users in their sample, more information was shared willingly in their social networks than was shared with the health app providers (VonHoltz et al., 2015).

A 'digital divide' among certain population groups can cause challenges with an app solution (Cronley et al., 2023). Seifert et al. (2021) found that older adults may not utilize information and communication technologies (i.e. smartphones, tablets, high-speed internet services, etc.) to their fullest. This is because they do not use the internet due to lacking skills, not having internet access, or cannot afford it. Furthermore, Reddick et al. (2020) found that people living in rural areas or low-income households also can experience low connectivity, which is crucial in app-based solutions based on real-time data collection. According to Milne and Watling (2019), mobile phone (and thus app) users usually are younger, and digital technology use varies greatly between individuals. Thus, it is necessary to consider how to deal with populations less likely to use smartphones, such as elders, those with little economic/technological access to mobile phones, and minority community members (Lee and Sener, 2020).

Theoretical framework

We use risk, diffusion, and privacy theories to answer the research question. When studying the connection between the perceived risk of a negative outcome and digital technology use, we will use Ulrich Beck's theory of 'risk society' (1999, 1992). This theory can be transferred to the smartphone app context because it explains people's fear of future negative outcomes (e.g., personal information stored being hacked, leaked, sold, or misused) using the concept of *risk*. According to Sørensen (2018), risk society theory is a useful analytical tool when studying conflicts that emerge between laypeople, scientific experts, and authorities concerning new technologies; it provides a framework of how consumers can be skeptical about a new product, which can appear irrational from the authorities or science perspective, but is perfectly rational from the lay perspective. Beck's theoretical framework has e.g. been used to study youth media non-participation (Chu, 2020), phishing (Okpa et al., 2020), and autonomous vehicle malware (Vassallo and Manaugh, 2018).

We use diffusion theory to explain how knowledge and interest in digital technology can affect participation. Diffusion theory (DT) (Rogers, 2002, 1995) is a process that describes how new technology spreads from innovators to consumers through stages. This diffusion process may also be applied to app-based travel surveys. This is because diffusion theory is useful when studying the adoption of new technologies (Kasilingam, 2020; Sriwannawit and Sandström, 2015). Diffusion theory has e.g., been used to study smartphone chatbots for shopping (Kasilingam, 2020), chatbots on bank websites (Hari et al., 2022), digital low-carbon innovations (Wilson et al., 2022), smartphone use (Kim et al., 2014), smart home technologies (Vrain and Wilson, 2021), and mobile banking apps (Tran and Corner, 2016).

Regarding varying reactions to the request to share data on movement, we use theory on privacy from psychology. James Rachels (1975) devised a general theory on why privacy is important, explaining why people can be hesitant to share even mundane personal information (Mooradian, 2009).

Risk society

According to Beck (1999, 1992), *risk* is the anticipation of a catastrophe, the nature of which has changed in the modern age, i.e., after WWII. Old risks, e.g., earthquakes and famine were natural disasters

external to human control. Modern risks are products of human-made scientific and societal changes, such as climate change, terror attacks, inflation, and the restriction of civil liberties (Beck, 2009). Modern risks are invisible and not tangible, concern everyone and it is impossible to ignore them (Joas and Knöbl, 2009). For example, we cannot see climate change as this is a slow, gradual phenomenon. However, there is a possibility of a catastrophic event somewhere in the future due to climate change. Further, in a risk society, choices are made based on a potential future rather than on past experiences.

In summary, risks are causal interpretations of potentially horrible future outcomes due to modern technology and societal development. Furthermore, not everyone perceives something as a risk (e.g., not everyone fears climate change, or their data being hacked). Thus, while some believe that the use of a particular technology represents a source of risk, others do not. If someone experiences risk as omnipresent, they have three potential reactions (Beck, 2009): denial, apathy, or transformation.

Science and technology cause modern risks but are also tools to understand and prevent them (Beck, 1992). Due to the increasing complexity of modern risks, the average person only perceives future menaces such as global warming because of scientific knowledge and discovery. As a result, people have to personally decide whether to trust or reject scientists' statements (Joas and Knöbl, 2009). Legal and scientific professionals and the mass media are central in defining the risks, and communicating them to the general public (Beck, 1992; Cottle, 1998). Since modern risks are imperceptible and based on personal interpretation, shifting narratives may cause people's interpretations of them to become changed, dramatized, or minimized (Beck, 1992). Without the mass media's visualization of risks, risks are nothing, because they cannot be anticipated (Beck, 2009).

Manufactured uncertainties are publicly manufactured risks, which are incalculable, uncontrollable, created by society, collectively imposed, and individually unavoidable (Beck, 2009). The public dramatization of manufactured uncertainties often affects the most innovative branches of science because the pace of development is so fast that it exceeds society's imagination. This can result in fears of an inexistent future, which is difficult to rebut for scientists (since it has not happened yet), and can threaten freedom of research.

Diffusion theory

According to Rogers (2002, 1995), (1) an innovation (idea, practice, object), (2) is communicated through channels (e.g., mass media and social networks), (3) over time (4) to members of a social system. The extent to which an innovation is successful depends on the (a) relative advantage (is it better than the alternatives?), (b) compatibility (is it consistent with existing values, past experiences, and current needs?), (c) complexity (is it difficult to use?), (d) trialability (can it be experimented on?), and (e) observability (are the results visible to others?). Governments, communities, organizations, or corporations can use different tools to spur or stifle adoption, thus affecting an innovation's success (Rogers, 1995). Governments can e.g., impose mandates, award monetary incentives or deterrents such as tax credits, to influence the adoption of innovations. Similarly, corporations can advertise or adjust pricing. The *rate of adoption* is the relative time it takes for an innovation to be adopted by a social group.

Interpersonal relationships are more important than mass media in influencing attitudes toward an innovation (Rogers, 2002, 1995). According to DT, fewer people evaluate an innovation based on scientific research, but instead evaluate an innovation based on subjective evaluations of others who have already adopted the innovation. The *innovation-decision process* is the process where an individual goes from (1) having knowledge of an innovation, (2) forming an *attitude* about it, (3) deciding whether to reject or adopt it, (4) *implementation* (5) *confirmation* of decision (i.e. spreading the word) (Rogers, 2002, 1995). Rogers (2002, 1995) defined *innovativeness* as the speed with which an individual adopts any given innovation. Rogers (2002) categorized people into five groups based on innovativeness: (1) *innovators* (the first group to adopt an innovation), (2) *early adopters* (the second group to adopt an innovation—they have the highest degree of opinion leadership in most social systems, i.e. potential adopters look to this group for advice and information), (3) *early majority,* (4) *late majority,* and (5) *laggards* (the last group to adopt an innovation—they will only accept an idea when they are surrounded by peers who have adopted and are satisfied with it). The relative proportion of each group is illustrated in Fig. 1.

Privacy

According to Rachels (1975), the need for privacy on any particular issue depends on your ties (i.e. the type of relationship) with the individual you are considering sharing your information. Rachels discusses the importance of an individual having control of the information, and access to personal space. "Sensitive information" is not universal, meaning that what is sensitive for one person may not be sensitive for others (Francis, 2008). Some may consider for instance their age to be sensitive information, while others may not.

Methodology

This chapter details the methodology used for the paper, including typology development, data analysis approach, the coding process, use of probes, privacy, and anonymization. Lastly, some potential limitations are presented. We use data material from two qualitative studies, one using focus groups (FG) and one using personal interviews (PI). We combine the data material because the FG inspired the data collection of the PIs: The focus groups were conducted before a student travel survey pilot using a smartphone app (Svaboe et al., 2021). During FGs, we identified some interesting components concerning fear of tracking technology (i.e. risk) and interest in the digital technology itself, which could affect participation (i.e. new technology interest). However, we had not included all relevant questions and only included students in the FGs. Thus, we conducted PIs in 2021. This is why there is a time gap between data collections. Both data materials are used in the typology development.

Fig. 2 illustrates the process from data collection to typology development, similarities and differences between FG and PI in choice of population, recruitment strategy, probe (stimulus material), and data processing.

Typology development

A typology is a schematic compilation of different analytical categories, phenomena, or findings, often with multiple theoretical dimensions (Tjora, 2021). The purpose of developing the typology is to have a model to explain people's behavior when they are presented with new digital technology. Typologies are typically visualized using simple four-field models, allowing for a convenient presentation of empirical findings. The four-field model has two dimensions (at a time): horizontal and vertical. In this paper, we use these dimensions to visualize *value* dimensions connected to the use of new digital technology. The dimensions can be used to create a two-dimensional area with four different ideal types (Tjora, 2021).

Ideal types are conceptual tools developed by Max Weber as a result of a methodological discussion (Hekman, 1983). They are one-sided exaggerations meant to capture an essence, and are not mirrors of the real world (Ritzer and Stepinsky, 2014). This paper uses ideal types as they are described at the most basic level (Ritzer and Stepinsky, 2014, p. 119): "concept constructed (…) to capture the essential features of some social phenomenon". The social phenomenon herein is the reaction to new technology. The ideal types are useful to explain the complexity of respondent reactions in a simpler, more synthesized way, making their reactions easier to understand. The prevalence of responses is not crucial to the analysis presented. Thus, there is no discussion of proportions or frequency of the different reactions.

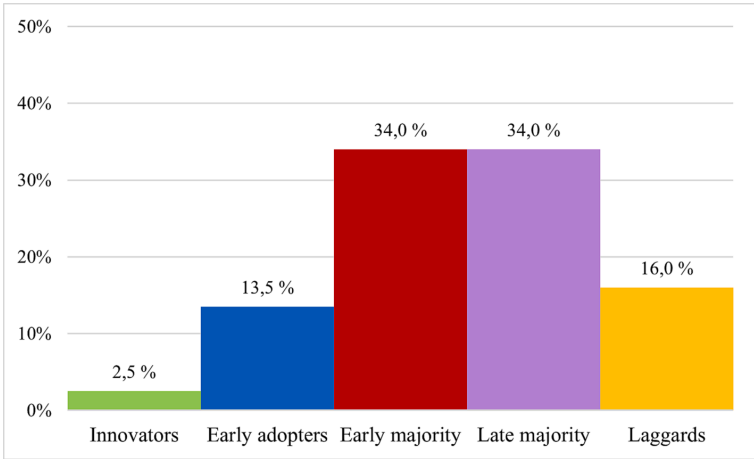

Fig. 1. Adoption of innovation (based on Rogers, 2002).

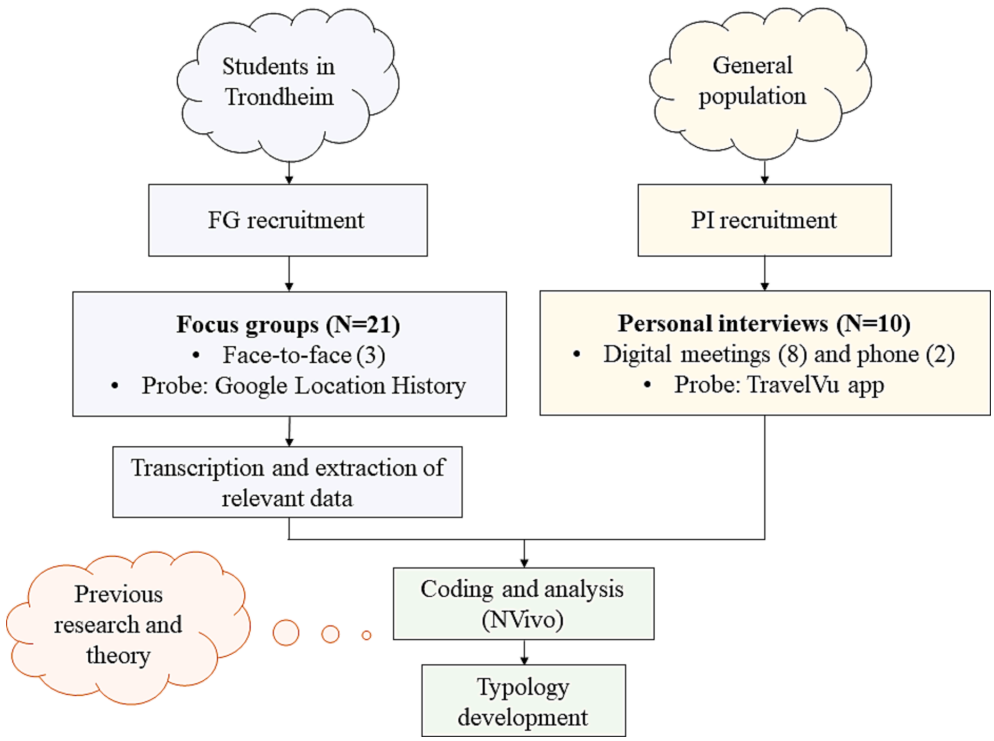

Fig. 2. Illustration of the process.

Data material

The research is based on parts of transcriptions from three focus group interviews in January 2017 and notes from ten personal interviews in May-July 2021. These data sources are described in more detail in the following two subchapters. Both FG and PI used non-random convenience sampling (Ringdal, 2018) and were semi-structured (Tjora, 2021), with recruitment from social media (information about the study was posted online) and personal networks (friends, colleagues, acquaintances, etc. recruiting on behalf of the interviewer, i.e. snowballing). FG recruitment also happened in lectures at NTNU.

Focus groups

The focus groups consisted of university students that had studied for at least one semester. Two groups had eight informants, while the third group had five. The interviews lasted 60–120 min, and audio was recorded, which was subsequently transcribed. In a portion of these interviews (approximately ¼), the possibility of using new digital technology in travel behavior research, privacy, and the use of tracking data was discussed. Transcriptions from these discussions were extracted from the data material and coded. Informants originated from different geographical places in Norway but lived in Trondheim at the time of the interview. The informants studied at different campuses, thus having different academic backgrounds.

Personal interviews

The personal interviews lasted 30–74 min. Due to COVID-19 restrictions, interviews were conducted as digital meetings (eight interviews), and over the telephone (two interviews). Informants were recruited under the following criteria: (1) to avoid bias, informants could not work within the transportation research field or at universities, (2) they were to be at least 30 years old to ensure that they had sufficient life experience and probability of having responded to a survey of some sort), (3) they needed to own a smartphone, and (4) they were not students (this group had already been studied in the FG).

After 4–5 interviews, the same stories and opinions started to repeat, and fewer and fewer new elements emerged. Interviewing was discontinued when no new information emerged, i.e., at the saturation point (Tjora, 2021). Thus, ten interviews are seen as sufficient. The informants, five men, and five women lived in different geographical places in Norway and were 30–81 years old. A description of the informants is presented in Table 1.

Thematic analysis

The data material was thematically analyzed at a semantic level (Braun and Clarke, 2006), i.e. combining codes to identify a common *theme,* where the themes were identified based on the explicit responses of the interviewees regarding the topic. A theme is a pattern that captures something important about the data in the context of the research question (Braun and Clarke, 2006). Based on previous research (Julsrud and Krogstad, 2018; Svaboe et al., 2021; VonHoltz et al., 2015), the researchers knew that the data material would include, e.g., new digital technology interest and risk as salient components, and that there would be differing opinions regarding smartphone use. These aspects were therefore used in typology development prior to coding.

The thematic analysis involved data material coding in NVivo, each with its distinctive meaning. Subsequently, a second round of analysis was done to remove irrelevant codes, combine overlapping codes and identify themes. The main value dimensions were structured as parent codes during this part of the analysis, and themes were created as child codes. For example, *fear of risk* was a parent code, and statements concerning risk were ordered as underlying child codes. Finally, child codes were sorted into six main themes, which are used to answer the research question.

Table 1
Description of informants.

Informant	Occupation	Age group	Gender
1	Coordinator	40–49	Male
2	Pensioner	80 +	Male
3	Musician	40–49	Male
4	Executive	60–69	Male
5	Bioengineer	30–39	Female
6	Administrative leader	60–69	Male
7	CEO	30–39	Female
8	Kindergarten teacher	30–39	Female
9	Principal	60–69	Female
10	Teacher	50–59	Female

Probes

Probes (stimulus materials) were used in both the focus groups and the personal interviews to get them to react to smartphone technology that tracks movement. The FG informants were given a presentation of the features of Google Location History (GLH). GLH is the location history of the mobile device, which is collected when the phone is signed into a Google Account and Location History is enabled. This introduced the informants to the technology and facilitated discussions on how they perceived it and felt about using it for research purposes.

In the PIs, informants were presented with TravelVu, an app developed to collect travel survey data. We used TravelVu instead of GLH in the PIs because we wanted an example of an app specifically made for travel behavior research. TravelVu passively registers trips and activities based on smartphones' Wi-Fi, accelerometer, and GPS data. The user verifies and corrects the trips and activities. The algorithms learn from the corrections and suggest each user's most probable travel behavior, provided the app is used over time. These apps were presented to informants as examples of such technology, and not as endorsements of their use. Although the aim was to avoid informants feeling pressured into voicing approval about the use of such technology, the interviewer emphasized that they had no personal stakes in whether the informants gave positive or negative comments about using an app for data collection. The participants were informed that the purpose for their participation was to identify tools to improve travel survey data collection, and not to, e.g., develop an app. The interviewer also made it clear that there were no right or wrong answers.

Privacy and anonymization

All participants were informed that they could withdraw from the study at any time, without providing a reason. All informants were anonymized and given a pseudonym. In the personal interviews, a notetaker was used, and consent to participation was collected at the beginning of the interview. A recorder and a notetaker were used during the focus group interviews. All informants in the focus groups signed a notification form to document voluntary participation.

Limitations

Two personal interviews were conducted by telephone, hindering the use of visual probes when discussing the use of smartphone apps for data collection. These participants received the presentation without visual aids. It is not likely that this resulted in significant data loss. One informant (elderly) interviewed by telephone did not use apps, with smartphone use limited to texting and calling. The other informant who was interviewed by phone had a high knowledge of apps and smartphones and had no problem understanding the concept.

In the PIs, not all age groups were interviewed because we prioritized reaching a diverse group of adults.

Lastly, a time gap between the two data collections could affect public perceptions (e.g., share of people interested in participating in a smartphone TS). However, we focus on identifying underlying value dimensions, not proportions.

Analysis

After coding the data material, we identified six key themes:

- Smartphone use.
- The feeling of being monitored.
- Mass media affect perceptions of technology.
- Personal statistics are fun.
- Participation is tedious.

- Control of information.

In this chapter, we present each theme with examples from the data. Then, we use the themes to develop the typology of reactions to smartphone apps.

Smartphone use

Among other background inquiries, personal interviews opened with a question regarding the extent to which participants tended to have their phones with them throughout everyday activities. This question aimed to map the risk of potential smartphone TS participants leaving their smartphones behind, resulting in data loss. Although "everyone" has a smartphone and brings it with them "everywhere", statements from PIs reveal that they use them differently. One informant had implemented routines to reduce at-home smartphone use, putting them away in a designated place. Another informant had to put their phone away during work hours. However, all PI informants expressed one variation of "always" having their phones with them, unless they actively put them away.

Always
PI informant 10 on how often they have their phone with them
It is always available. The only time it leaves the body is when it is on the bedside table
PI informant 4 on how often they have their phone with them

Even though the PI informants bring their phones with them "everywhere", in a purely physical sense, this does not mean they would be inclined to participate in smartphone TSs. And even if they were, not all informants were proficient in app use in general, so they would not necessarily be able to correct or verify trips in an app, if required. Secondly, not all PI informants had GPS and mobile phone data activated continuously.

Not that often
PI informant 5 on the question of how often GPS and mobile phone data is activated
Almost daily
PI informant 6 on the question of how often GPS and mobile phone data is activated
GPS is rarely activated
Informant 9 on the question of how often GPS and mobile phone data is activated

For the informants who do not have the necessary settings on constantly, passive data collection would likely result in data loss.

Feeling of being monitored

After the probe presentation, immediate reactions differed between participants in focus groups and personal interviews. Some FG informants drew immediate parallels between the app presented, surveillance, and monitoring, and some used the term "Big Brother". Some FG participants had issues with GLH being part of Google. All FGs brought up the following paradox: Participants "recognize" that they are being monitored by "big tech", which sells information about their whereabouts, search history, and activities in which they decide to engage. At the same time, however, participants get wary when presented with smartphone TS apps. It is seemingly worse to willingly participate in a smartphone app survey than to passively accept "terms and conditions" without reading them because then they *understand exactly* what they give away in a TS. It appears as if there is a difference between monitoring "being done" without their knowledge by corporations and actively consenting to be registered.

So there is a little difference in the fact that I just have my phone and it (Google) knows where I have it, that's fine, but if I actually actively go in and say "yes, follow me where I go" then I think there is a difference between people, even though it may be much the same.
FG 1 participant reflecting on consent and tracking technology

Some informants said they would be more willing to use an app created by an institution they trusted. Other informants did not find it problematic to be tracked when presented with the idea of a smartphone app TS: "We are already being monitored everywhere, so why not? " Such informants were naturally more optimistic. To them, movement tracking did not feel like an invasion of privacy.

I don't see any problems with it (tracking) really because you are surely being monitored on so many apps
FG 1 participant reflecting on tracking movement for research purposes

In the PIs, a similar split was observed. Some informants expressed that an app that tracks movement gave negative associations, drawing parallels with surveillance, monitoring, and the concept of "Big Brother is watching you", expressing that collecting and sharing such information was problematic.

They get a "Big Brother feeling"
PI informant 5 after the presentation of the probe
Information about individuals is collected and distributed without us having a full understanding of its purpose and scope. A bit like "Big Brother sees you". I understand the benefits, but I also have concerns.
PI informant 9 after the presentation of the probe

Others, however, saw no problem with sharing smartphone tracking data.

Yes, of course, no problem at all
PI informant 1 on whether they would participate in a smartphone-based TS (after probe)
The app is harmless and doesn't collect sensitive information
Informant 4 on whether they would participate in a smartphone-based TS (after probe)

Personal statistics are fun

Some of the FG informants who were positive about the app were also excited by the possibility of receiving personal statistics on travel behavior.

Student A: seems a bit exciting then, and maybe a bit fun to join in just to try it out?
Student B: Yes, and just see for yourself, have I walked that far?
Student A: Yes
FG 3, two students reflecting after the probe was introduced
Student C: I think it would be exciting to get the results myself
Student D: but when you see your travel behavior and so on, and maybe see it in relation to others, or means of transportation in relation to each other… I think it would be interesting… then I think I could download it, and see how I use transportation and maybe in relation to myself or yes in relation to the different means of travel and in relation to others
Student F: like if you walk a lot more than the average or something then it makes you feel good
{group laughter}
FG 1, 3 students reflecting on using an app that tracks movement

The same enthusiasm was found in some PI participants: Possibilities for examining their travel behavior were seen as beneficial, much like an exercise app is (but with more functions, since it includes car, public transport, taxi, etc.).

It is nice to get an overview of your activity. The informant and their partner are trying to walk more, so getting an overview of walking was nice
PI informant 4 reacting to the probe
Technology is fun
PI informant 6 on the concept of tracking movement with an app

Some informants considered what type of statistics they would find interesting, e.g., CO_2 footprint and transport mode distribution.

Mass media affect perceptions of technology

Fears of surveillance were not connected solely with the technology. Some FG informants discussed how governments could potentially

"snoop" at sensitive information.

If you get curious… those at NAV[1] who have looked up friends and acquaintances without… but yes, searched on their history – they became cases because they were curious… and so are we

FG 3 participant on curiosity and data security

[1] Norwegian Labour and Welfare Organization.

Some FG informants discussed positive experiences with fitness and exercise apps. The PIs were conducted shortly after a media storm surrounding a COVID-19 tracking app, which might have affected the perceptions of tracking technology. After the probe was introduced in the PIs, many drew parallels between TravelVu and the Norwegian COVID-19 tracking app, *Smittestopp*. Smittestopp was promoted through a large P.R. campaign before release, aiming to maximize the number of downloads. Shortly after launch, however, Smittestopp was criticized for privacy violations, resulting in low usage, P.R. damage, and a subsequent re-launch of the app (Amnesty International, 2020; Fjeld, 2020; Tjoflot, 2021; Zondag and Wergeland, 2020). The perception of Smittestopp varied amongst PI informants. Some discussed the positives of having an app for contact tracing, using similar arguments as during the initial promotion of Smittestopp.

In the new world, apps seem to be the way to go. It seems to work

PI informant 5 reflecting on the increased use of apps in today's society

We have benefited a lot from this technology. So it gives us a lot of opportunities for quick and fast and good communication. And we use that infection tracking app, so that's smart.

PI informant 9 on the use of tracking technology

Others, on the other hand, discussed how the app violated privacy using the same arguments as critics in the media.

The informant stated that they did not download Smittestopp because it is healthy to be skeptical in today's society

PI informant 8 on Smittestopp

All PI informants discussed the positives (tracking COVID-19) and negatives (privacy concerns) of being monitored. Their comments largely reflected the media campaign and scandals from the media.

Participation is tedious

Some informants stated that participation in app-based TS surveys would demand too much of the user. Those who found it tedious could be categorized into two groups:

1. those who would have problems with participating due to a lack of knowledge about how apps work, e.g., those who do not use smartphones beyond texting and calling.

Without a presentation, participation would be difficult and confusing. Apps can't be too complicated. Editing (validating trips in the app) makes it more complicated.

PI informant 6 after the probe presentation

2. those who would not necessarily have a problem with using an app but did not find this approach interesting as presented. For them, participation would be an inconvenience or a bore. Therefore, participation would only be a "time thief". One FG participant found the act of just opening an app to be an exhausting undertaking.

…think the less active you must be… just downloading an app can be a barrier because, actually, I don't know if there are others who think like that, but I find it annoying when everything has to have its own app then, eh, it's a bit cumbersome unnecessary

FG 3 participant on the thought of using an app as a data collection tool

We are drowning in apps

PI informant 7 on using smartphones in research

The app sounded very comprehensive and easy to de-prioritize… by asking someone to participate, you are asking them to de-prioritize their own time.

PI informant 8 on participation in a smartphone-based TS

Control of information

Several FG and PI informants had as prerequisites for participation in smartphone travel surveys that the institution responsible for data collection was professional, recognizable, and provided documentation of proper data processing and storage.

The purpose of the survey must be clearly stated, and why it is relevant, is what we have talked a lot about then, and the purpose, and why the purpose is important … why should you know where I travel during the week? And what can you use this information for?

FG 3 participant on what information they would need before sharing information

I think it would be fine too as long as it's not a horrible commercial company that wants to use it for advertising and stuff like that… if it's for research and stuff like that then sure

FG 1 participant on whether they would share smartphone movement data

I think it depends on who's asking to get the data because not everyone is willing to share data on where you travel… but you need to know that it is confidential.

FG 2 participant on getting people to share GLH data

Important to have integrity, show that no one else will have access to the data and that it will only be used for research. Important that no one should be tracked, taken for anything (after data collection).

PI informant 1 on integrity and data safety

You must be clear about who is collecting. If it is for research purposes it is more straightforward, but if it is a commercial actor, it is less interesting to be involved.

PI informant 6 on data collector

It is important to ensure that data is processed securely.

PI informant 8 on data safety

Such information would ensure participants that no business, enterprise, or public institution would inappropriately or carelessly handle their personal data. In addition, providing such documentation would establish trust. *Trust* was cited by many as a prerequisite for voluntarily providing data. Any presence of doubt in the data collector or app provider is very powerful and would be disastrous for any TS. Since the immediate personal gain of TS participation is limited or nonexistent, willingness to participate plunges if any doubt concerning information safety materializes.

Value dimensions

Based on the coding, previous research, and theoretical framework, six themes were developed in the analysis. These are used to describe two value dimensions used in the typology: *fear of risk* and *technology interest*. Ulrich Beck's 'risk society' is used to develop the value dimension concerning *fear of risk* (Y-axis), and diffusion theory is used to develop the value dimension *technology interest* (X-axis).

Dimension 1: Fear of risk

The first dimension, *fear of risk*, is an emotional component regarding the concern that some negative future outcome will materialize from using the technology. E.g., companies and/or governments will violate participants' privacy and use the information inappropriately, carelessly, or otherwise leave the data susceptible to hacking. The feeling of risk does not necessarily relate to the technology directly, but the technology *mediates* the feeling. It is a *perceived risk* that is socially constructed. Actors that can affect the perceived risk are, e.g., mass media, social media, friends, family, and politicians.

This is based on the following themes: (1) *Feeling of being monitored*, (2) *Mass media affect perceptions of technology* and (3) *Control of information*.

Dimension 2: Technology interest

The second dimension, *technology interest*, has to do with general knowledge and interest in smartphone apps. Technology interest affects whether participation in a smartphone-based travel survey is perceived as tedious or not. Those with a low technology interest typically have limited to no knowledge of apps and thus do not use them unless they *must*. Those who have a high technology interest know more about apps and would find them easier to use, and perhaps even fun or useful.

It is based on the following themes: (1) *Smartphone use*, (2) *Personal*

statistics are fun and (3) *Participation is tedious*.

Typology of reactions to smartphone apps

Fig. 3 details a typology of reactions to the app-based TS technology, with two dimensions and four ideal types. The typology assumes that underlying value dimensions affect the probability of acceptance of the technology. The risk is perceived and personal. The possibility of the data being mishandled from an objective standpoint is irrelevant. The fear of risk is a fear of a potential future where participation has led to a negative outcome, and not necessarily a fear of what will happen during participation. For instance, a person can fear that the data collected in a TS will be sold, leaked, hacked, or used against the person in unforeseen ways in the future, without fearing the TS itself. The outcome is still that they will not participate in the TS.

Ideal types

The *Risk avoider* has no interest in the technology and has a high fear of risk. Thus, the *Risk avoider* is unlikely to participate in travel surveys *at all,* due to the perceived sensitivity such individuals harbor related to reporting their whereabouts. The combination of high fear of risk and low technology interest makes it unlikely that adoption of new technology will happen willingly.

The *Skeptic* is knowledgeable about smartphone apps but is very concerned about privacy and has fears of being monitored. As a result, the *Skeptic* is wary of their digital trail, and data sharing, and is unlikely to participate in smartphone app-based surveys.

The *Excluded* does not fear being monitored but is uninterested in using the technology, or is unable to do so, owing to a lack of necessary skills. When adapting new technology, the Excluded is not actively avoiding technology due to fear of risk and should thus be understood as more of a laggard.

The *Technology optimist* is highly skilled in using smartphone apps and does not worry about being monitored. Technology optimists would be categorized as innovators when it comes to adapting new technology. They would participate in smartphone app surveys out of sheer interest in the process and the resulting statistics.

Discussion

In this paper, we attempt to explain why recruitment is challenging in app-based travel surveys, by developing a typology of reactions to smartphone apps, based on two qualitative studies. The aim is to improve the current understanding of respondents' reactions to new technology. Six main themes were identified, which were used to describe two dimensions that explain reactions to the use of smartphone technology in travel behavior research. Many reactions to smartphone app travel surveys are explained by the two dimensions presented in this chapter: 1) *technology interest* and 2) *fear of risk*.

The typology reveals why recruiting respondents to a smartphone travel survey is so challenging: the Technology optimist is the only one that would willingly participate. In travel surveys using traditional methods, the Excluded would *at the very least* consider participation, while it is unlikely that the Skeptic and Risk avoider would participate in travel surveys irrespective of data collection method since most travel surveys ask about whereabouts and background information, which would presumably be considered too risky to share.

Still, using the theoretical framework in the paper, change in perception and adoption of technology is possible using e.g., social networks, assuming that the adopters can communicate the benefits of using the digital technology to the non-adopters. The fact that the Norwegian government's media campaign affected the tracking technology responses indicates that mass media can affect the perceptions of new technology. Further, smartphones can serve a purpose in TS data collection as an option for those who prefer it. For example, the interest in smartphone technology could make some people more interested in participating, and for these individuals, personal statistics could incentivize their participation. For some people, the app can be understood as both an interesting innovation, and as something that can provide immediate value, or a reward, such as personalized statistics on CO_2 emission and suggestions for reducing it. Alternatively, the app could provide information on how to reduce travel time or costs.

A possible explanation for the low response rates in smartphone-based TS is that we are currently in a period where *innovators* have adopted tracking apps, and some *early adopters* are beginning to use them. However, early adopters have yet to confirm the innovation. In other words, the widespread use of smartphone apps in large-scale travel

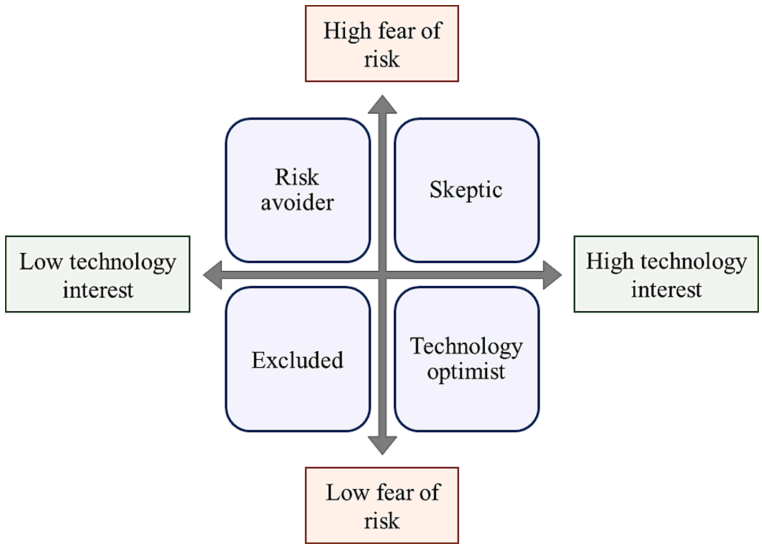

Fig. 3. Typology of reactions to smartphone apps.

surveys has not yet materialized, as the diffusion process is still in its early stages, assuming that the innovation will eventually be adopted.

Smartphone apps may facilitate data collection from some hard-to-reach groups that would not otherwise participate in travel surveys using other survey modes, such as telephone interviews, postal surveys, or face-to-face interviews. Thus, data collection using smartphones could presumably improve knowledge of travel behavior. However, exclusively relying on smartphone app data may not provide sufficient representativity in the sample. Rather, travel behavior researchers should utilize the strengths of new technology while being aware of its potential drawbacks, relying also on traditional methodologies.

People's perceptions of technology risk can affect the representativity of samples in travel surveys. E.g., if risk perception is related to age or technology interest, which may themselves be linked, smartphone travel surveys may under- or over-represent certain demographic groups. The elderly typically have less experience with smartphone use, which could lead to them being inadvertently excluded from a smartphone travel survey. This issue could be overcome using multiple data collection options, accounting for potential survey mode effects.

The results obtained from personal interviews may, to some extent, have been affected by the scandal of Smittestopp and pandemic-related lockdown restrictions. Still, these two potential issues highlighted some critical technology acceptance properties. First, people appear to be willing to download an app that tracks their movement, given the right circumstances (according to the Norwegian Institute of Public Health, Smittestopp was downloaded 1.3 million times (Norwegian Institute of Public Health (NIPH), 2022). Second, the public's trust in the government in Norway is high. Third, the sentiment conveyed about such an app through media is paramount to its success (many people downloaded Smittestopp at launch, despite its technical issues and the subsequent media storm). Fourth, the pandemic led to accelerated adoption of digital technology, exemplified through e.g., Teams, Zoom, and online shopping). This was perhaps a positive for this study, as undertaking qualitative interviews online would perhaps have been more problematic, had people not already started transitioning to digital platforms for pandemic-related reasons. Finally, digital recruitment also made the geographically diverse group of informants possible.

There are three potential challenges to the robustness of the typology: 1) the time gap between data collections (2017 and 2021), 2) the age difference between the FGs and PIs, and 3) not all age groups being included for both genders in the PIs. Regarding the first, when studying the reactions in both data sets, we found that the underlying value dimensions were present in both data materials. Regarding the second, we found both positive and negative reactions among the elder and younger informants in the PIs. Regarding the third, since we are not discussing proportions or sizes of groups, it should not pose a problem for identifying value dimensions; there were informants with high/low fear of risk and technology interest among the younger and older informants in the PIs, and the value dimensions were identified in both the FGs and PIs. Thus, we argue that the potential challenges of using both data materials are outweighed by the increased data richness of using both FGs and PIs.

Conclusion

This paper proposes a typology of reactions to smartphone apps for an improved understanding of people's reactions to smartphone apps for travel behavior research. The typology has two dimensions (*fear of risk* and *technology interest*) and four ideal types (*Skeptic, Risk avoider, Technology optimist, and Excluded*). The reaction to the use of smartphone technology depends to a large extent on their perceived risk of participation and their interest in the technology.

Implications

The proposed typology explains why recruitment is challenging when using smartphone tracking for travel survey data collection. If a person fears monitoring, they are unlikely to participate. Similarly, if the person has a low interest in app use, smartphone TS participation appears tedious, and the individual will not participate. In fact, the technology optimist is the only person "certain" to participate in smartphone app surveys.

Further, if transport researchers, or others involved in the undertaking, were to violate potential respondents' sense of privacy, this could tarnish the public's perception of even unrelated research that uses similar digital tools. Any such breach of trust would hinder researchers' current and future ability to obtain information about citizens' travel patterns due to the fear of risk. In some sense, transport researchers working on the potential use of smartphone data are responsible for the future of travel behavior research.

While this typology is developed with travel behavior research in mind, it can be used for studying other technologies and perceived risks. It can, for instance, be useful when studying the reactions to pandemic-related tracking apps and shed light on the extent to which the public accepts these. Further, the typology may explain why some individuals may be skeptical of 'new' technology, e.g., autonomous vehicles.

Recommendations

Future research could focus on the recruitment of respondents with different understandings of risk. It would also be valuable to study strategies for combining novel and traditional methods, making participating across age groups and technological interests easier to compensate for non-response. For example, giving a subsample of a travel survey the option to pick between multiple administration modes (CATI, CAWI, smartphone, face-to-face CAPI, etc.), to understand better which groupings tend to prefer each administration method. Combining data collection tools could mediate some non-response challenges because different groups might prefer different ways of reporting travel. However, a multi-mode solution demands that the data collector has a plan for correcting potential mode-effects.

The concept of gamification involves motivating and engaging users through tactics commonly found in computer games. It is gaining popularity across disciplines and could presumably also be used to increase positive sentiment toward travel surveys. While individuals with a high technology interest would presumably be affected most, gamification may even help the app be perceived as more "friendly" and approachable by the more skeptical groupings of the typology. Such strategies may, however, end up sabotaging their success, as highly gamified TS apps could potentially affect the travel behavior they're meant to record. Such solutions should be treated carefully. Nonetheless, such outcomes may also be beneficial: If gamification increases modal shares for soft modes through encouraging lower emissions or promoting sustainable travel, this could be seen as a net win.

Since there are variations within population segments, more qualitative interviews should be conducted to improve smartphone use knowledge. There is varied knowledge amongst e.g., elders regarding technology. Some younger generations may have the necessary knowledge, but still might be "tracking"-skeptics.

Improving all forms of digital data collection to reduce non-response, i.e., both smartphone apps and self-reporting computer interviews (e.g. CAWI) is important. Poorly designed interfaces can impede data collection since they reduce trust in the data collector and increase the respondent burden.

The next logical step with the typology of reactions to smartphone apps is to survey to quantitatively identify the proportion sizes of the reactions between population groups/segments. Travel survey designers could use this information to target data collection methodology, which could improve data quality.

CRediT authorship contribution statement

Gunnhild B.A. Svaboe: Conceptualization, Data curation, Formal

analysis, Methodology, Writing – original draft, Writing – review & editing, Visualization. **Arild Blekesaune:** Conceptualization, Writing – review & editing, Supervision. **Trude Tørset:** Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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Appendix

A. List of semi-structured focus group interview questions

C. Presentation of Google Location History (GLH)

3.1 Do you have previous experience/knowledge with GLH?

3.2 What are your thoughts on giving personal GLH data to research?

B. List of semi-structured personal interview questions

A: Background inquiries

1. Age
2. Work situation
3. How long have you owned a smartphone?
4. How often do you carry it in your pocket/purse (at home and outside)?

B: Surveys

1. Have you participated in a survey before?
2. What is the maximum time limit for participation in a survey (by phone, web, etc.)?
3. What is important for whether you participate or not?
4. Are there other factors that are important in determining whether or not you participate?

C: Travel surveys

Presentation of travel survey

1. Have you been approached to participate in this type of travel survey before?

Presentation of TravelVU

1. What are your thoughts on providing this type of information for research?
2. Would you be willing to participate in such a survey?

D: Register data

Presentation of register data

1. What are your thoughts on making greater use of this in research?

E: Closing questions

1. It is increasingly difficult to get people to participate in surveys, including travel surveys. Do you have any suggestions on how to increase participation?
2. What is the ideal survey? (Time, gifts, incentive, phone, web, app)
3. Do you have any other thoughts about using GPS and bluetooth (and register data) in research?

PART 3

Contents

Appendix A. Questionnaires

A.1. Student pilot

1. Kjønn:
□ Mann
□ Kvinne
□ Hen
2. Hvilket år er du født?
Fødselsår: _____
3. Hvordan bor du?
□ Sammen med foreldre
□ Leier hybel/leilighet
□ Egen bolig
4. Er du folkeregistrert i Trondheim?
□ Ja
□ Nei
5. Har du barn?
□ Ja
□ Nei
6. Har du førerkort for bil?
□ Ja
□ Nei
7. Hvordan betaler du for kollektivtransport (buss, trikk, tog)?
□ Periodebillett
□ Enkeltbillett
□ Reiser aldri med kollektivtransport
8. Hvilke av følgende transportmidler har du tilgang til? (Flersvar)
□ Personbil/stasjonsvogn
□ Motorsykkel/moped
□ Varebil
□ Sykkel
□ El-sykkel
□ Ingen
9. Hvilket nivå studerer du på?
□ Fagskole/Bachelor, deltid
□ Fagskole/Bachelor, heltid
□ Master, deltid
□ Master, heltid
□ PhD
10. Hvor studerer du (hovedcampus)?
□ Gløshaugen
□ Dragvoll
□ Kalvskinnet
□ Rotvoll
□ Øya
□ DMMH
□ Tunga
□ Olavshallen
□ Elgeseter
□ BI
□ Moholt
□ Tyholt
□ Annet: _____

11. Er du aktiv i frivillig arbeid?
□ Ja, mer enn 10 timer i uka
□ Ja, mindre enn 10 timer i uka
□ Nei
12. Hvordan reiser du vanligvis til hovedcampus?
□ Kjører bil
□ Er bilpassasjer
□ Bruker kollektivtransport
□ Sykler
□ Går
13. Har du deltidsjobb?
□ Ja
□ Nei

A.2. Trondheim I

1. Hvilket kjønn er du?
    a. Mann
    b. Kvinne
    c. Ønsker ikke oppgi
2. Hvilket år er du født? _____
3. Har du mer enn én bostedsadresse? (f.eks. som student eller pendler)
    a. Ja
    b. Nei
    c. Ønsker ikke oppgi
4. Har du førerkort for bil?
    a. Ja
    b. Nei
    c. Ønsker ikke oppgi
5. Hvor mange biler har husholdningen tilgang til (inkludert deg selv)?
    a. Personbil (bensin): _____
    b. Personbil (diesel): _____
    c. Personbil (elektrisk): _____
    d. Personbil (hybrid: bensin og elektrisitet): _____
    e. Hybridbil (hybrid: diesel og elektrisitet): _____
    f. Låner bil av slektninger/venner/bekjente: _____
    g. Firmabil: _____
    h. Privat-leasing bil: _____
    a. Annet: _____
    b. Nei
    c. Vet ikke
6. Er du med i en bildeleordning?
    a. Ja
    b. Nei
7. Eier eller disponerer du?
    a. Vanlig sykkel, i brukbar stand
    b. El-sykkel
    c. By-sykkel (har app eller kort)
    d. Moped/scooter
    e. Motorsykkel (MC)
    f. Annet (spark, sparkesykkel, ståbrett eller lignende)
    g. Ingen av disse
8. Hva regner du som din yrkesstatus eller ditt hovedgjøremål?
    a. Yrkesaktiv heltid, inntektsgivende arbeid
    b. Yrkesaktiv deltid, inntektsgivende arbeid
    c. Hjemmeværende/omsorgsarbeid i hjemmet
    d. Går på skole/studerer
    e. Militærtjeneste/siviltjeneste
    f. Fødsel- og foreldrepermisjon
    g. Alderspensjonist, AFP eller andre tidligpensjonsordninger
    h. Arbeidsledig, uten inntektsgivende arbeid
    i. Annet: _____
9. Har du fast oppmøtested på jobben? (Et oppmøtested man drar til minst 50 prosent av arbeidsdagene i løpet av et år)
    a. Ja
    b. Ja, jobber hjemmefra
    c. Nei

    d. Vet ikke
10. Du har svart at du ikke reiser fram og tilbake til jobb hver dag. Hva gjør du de arbeidsdagene du ikke reiser til/fra jobb?
    a. Arbeider hjemme
    b. Arbeider hjemme og drar derfra til evt. møter/kunder/pasienter
    c. Drar direkte hjemmefra til møter/kunder/pasienter etc.
    d. Overnatter på/nær tjenestested/arbeidsplass
    e. Konsentrerer full arbeidstid på færre dager
11. Har du fast arbeidstid, fleksibel arbeidstid, skiftordning eller annet?
    a. Fast arbeidstid på dagtid
    b. Fast arbeidstid på natt
    c. Fleksibel arbeidstid på dagtid (fleksitid)
    d. Skift, turnus, nattarbeid mm
    e. Kan jobbe når jeg vil
    f. Annen ordning
12. Er du yrkessjåfør?
    a. Ja
    b. Nei
    c. Vet ikke/ønsker ikke oppgi
13. Hvordan betaler du for kollektivreiser?
    a. Periodebillett på app
    b. Periodebillett på reisekort
    c. Enkeltbillett
    d. TT-kort
    e. Vet ikke/ønsker ikke oppgi
14. Hvilke parkeringsmuligheter er det på arbeidsstedet?
    a. Gratis, god kapasitet
    b. Gratis, begrenset kapasitet
    c. Betalt, god kapasitet
    d. Betalt, begrenset kapasitet
    e. Vet ikke/ikke relevant
15. Får du dekket noen av følgende utgifter til arbeidsreisen (til/fra jobb) av arbeidsgiver?
    a. Bilutgifter, firmabil
    b. Bompenger
    c. Parkering (på andre steder enn det arbeidsgiver disponerer)
    d. Kollektivtransport
    e. Annet
    f. Nei, ingen
    g. Vet ikke/ikke relevant
16. Hvor mange personer er dere i husholdningen (inkludert deg selv)?
    a. 0-6 år: _____
    b. 7-10 år: _____
    c. 11-14 år: _____
    d. 15-17 år: _____
    e. 18-24 år: _____
    f. 25-45 år:_____
    g. 46-75 år: _____
    h. 75 år og eldre: _____
17. Har du/dere egen parkeringsplass i nærheten av der du bor?
    a. Ja, privat parkering

b. Ja, soneparkering
c. Ja, gratis gateparkering
d. Ja, parkeringshus
e. Nei
f. Vet ikke/ikke relevant

18. Er det mulig for deg å oppgi inntekten din i et intervall (kr før skatt)?
    a. Under 100 000
    b. 100 000 – 199 999
    c. 200 000 – 299 999
    d. 300 000 – 399 999
    e. 400 000 – 499 999
    f. 500 000 – 599 999
    g. 600 000 – 699 999
    h. 700 000 – 999 999
    i. 1 000 000 og over
    j. Ønsker ikke oppgi
    k. Vet ikke
19. Er det mulig for deg å oppgi husholdningens inntekt i et intervall (kr før skatt)?
    a. Under 200 000
    b. 200 000 - 399 999
    c. 400 000 - 599 999
    d. 600 000 - 799 999
    e. 800 000 - 999 999
    f. 1 000 000 - 1 599 999
    g. 1 600 000 - 1 999 999
    h. 2 000 000 og over
    i. Ønsker ikke oppgi
    j. Vet ikke
20. Hva er din høyeste fullførte utdanning?
    a. Grunnskole
    b. Videregående skole
    c. Høyskole/universitet – lavere grad (til og med 4 år)
    d. Høyskole/universitet – høyere grad (5 eller flere år)
    e. Forskerutdanning (7 eller flere år)
    f. Ønsker ikke oppgi
21. I hvilken sektor arbeider du?
    a. Privat næringsliv
    b. Organisasjonsliv (frivillige organisasjoner, stiftelser)
    c. Offentlig sektor (forvaltning, administrasjon, undervisning)
    d. Annet
    e. Ønsker ikke oppgi

Takk for at du svarte på undersøkelsen! Dersom du ønsker å være med i trekningen av 100 flax-lodd, vennligst skriv inn e-postadressen din eller send en e-post til smartrvu@ibm.ntnu.no med kodeord «rosenborg». Om du ikke ønsker å delta i lotteriet trenger du ikke fylle inn e-postadressen.

A.3. Trondheim II (Norwegian version)

Takk for at du deltar!

Vi ønsker å stille deg noen korte bakgrunnsspørsmål. Grunnen til dette er at det vil hjelpe oss med å forstå hvordan ulike grupper bruker transportsystemet. Før du starter å bruke appen, ber vi deg om å lese informasjonsskrivet.

-------sidebrytning-------

Bakgrunnsspørsmål

1. Hvilket kjønn er du?
    a. Mann
    b. Kvinne
    c. Ønsker ikke oppgi
2. Hvilket år er du født? _____
3. Hvordan fikk du informasjon om undersøkelsen?
    a. Brev i posten
    b. Via sosiale medier
    c. Flygeblad i postkasse
    d. Kontaktet på gaten/kjøpesenter
    e. Ble ringt
    f. Annet: _____

-------sidebrytning-------

4. Hvor mange personer er dere i husholdningen (inkludert deg selv)?
    a. 0-6 år: _____
    b. 7-10 år: _____
    c. 11-14 år: _____
    d. 15-17 år: _____
    e. 18-24 år: _____
    f. 25-45 år:_____
    g. 46-70 år: _____
    h. 70 år og eldre: _____
    i. Sum (automatisk kalkulert)

-------sidebrytning------

5. Har du mer enn én bostedsadresse? (f.eks. som student eller pendler)
    a. Ja
    b. Nei
    c. Ønsker ikke oppgi
6. Har du førerkort for bil?
    a. Ja
    b. Nei
    c. Ønsker ikke oppgi

-------sidebrytning-------

If 6 = a

7. Er du med i en bildeleordning?
    a. Ja
    b. Nei
8. Er du yrkessjåfør?
    a. Ja
    b. Nei
    c. Vet ikke/ønsker ikke oppgi

-------sidebrytning-------

9. Hvor mange biler har husholdningen tilgang til (inkludert deg selv)?
    a. Personbil (bensin/diesel/hybrid): _____
    b. Personbil (elektrisk): _____
    c. Låner bil av slektninger/venner/bekjente: _____
    d. Firmabil: _____
    a. Annet: _____
    b. Sum (automatisk kalkulert)
10. Eier eller disponerer du?
    a. Vanlig sykkel, i brukbar stand
    b. El-sykkel
    c. By-sykkel (har app eller kort)
    d. Moped/scooter
    e. Motorsykkel (MC)
    f. Annet (spark, sparkesykkel, ståbrett eller lignende)
    g. Ingen av disse
11. Hva regner du som din yrkesstatus eller ditt hovedgjøremål?
    a. Yrkesaktiv heltid, inntektsgivende arbeid
    b. Yrkesaktiv deltid, inntektsgivende arbeid
    c. Hjemmeværende/omsorgsarbeid i hjemmet
    d. Går på skole/studerer
    e. Militærtjeneste/siviltjeneste
    f. Fødsel- og foreldrepermisjon
    g. Alderspensjonist, AFP eller andre tidligpensjonsordninger
    h. Arbeidsledig, uten inntektsgivende arbeid
    i. Annet: _____

-------*sidebrytning*-------

If 11 = a or b

12. Hvilke parkeringsmuligheter er det på/ved arbeidsstedet?
    a. Gratis, god kapasitet
    b. Gratis, begrenset kapasitet
    c. Betalt, god kapasitet
    d. Betalt, begrenset kapasitet
    e. Vet ikke/ikke relevant
13. Får du dekket noen av følgende utgifter til arbeidsreisen (til/fra jobb) av arbeidsgiver?
    a. Bilutgifter, firmabil
    b. Bompenger
    c. Parkering (på andre steder enn det arbeidsgiver disponerer)
    d. Kollektivtransport
    e. Annet
    f. Nei, ingen
    g. Vet ikke/ikke relevant
14. I hvilken sektor arbeider du?
    a. Privat næringsliv
    b. Organisasjonsliv (frivillige organisasjoner, stiftelser)
    c. Offentlig sektor (forvaltning, administrasjon, undervisning)
    d. Annet
    e. Ønsker ikke oppgi
15. Har du fast arbeidstid, fleksibel arbeidstid, skiftordning eller annet?
    a. Fast arbeidstid på dagtid
    b. Fast arbeidstid på natt
    c. Fleksibel arbeidstid på dagtid (fleksitid)
    d. Skift, turnus, nattarbeid mm

e. Kan jobbe når jeg vil
f. Annen ordning

16. Har du fast oppmøtested på jobben? (Et oppmøtested man drar til minst 50 prosent av arbeidsdagene i løpet av et år)
    a. Ja
    b. Ja, jobber hjemmefra
    c. Nei
    d. Vet ikke

-------*sidebrytning*-------

If 16 = c

17. Hva gjør du vanligvis de arbeidsdagene du ikke reiser til/fra jobb?
    a. Arbeider hjemme
    b. Arbeider hjemme og drar derfra til evt. møter/kunder/pasienter
    c. Drar direkte hjemmefra til møter/kunder/pasienter etc.
    d. Overnatter på/nær tjenestested/arbeidsplass
    e. Konsentrerer full arbeidstid på færre dager

-------*sidebrytning*-------

18. Hvordan betaler du for kollektivreiser?
    a. Enkeltbillett
    b. Periodebillett (dag, uke, måned eller år)
    c. TT-kort
    d. Vet ikke/Annet
19. Har du/dere egen parkeringsplass i nærheten av der du bor?
    a. Ja, privat parkering
    b. Ja, soneparkering
    c. Ja, gratis gateparkering
    d. Ja, parkeringshus
    e. Nei
    f. Vet ikke/ikke relevant

-------*sidebrytning*-------

20. Er det mulig for deg å oppgi husholdningens inntekt i et intervall (kr før skatt)?
    a. Under 200 000
    b. 200 000 - 399 999
    c. 400 000 - 599 999
    d. 600 000 - 799 999
    e. 800 000 - 999 999
    f. 1 000 000 - 1 599 999
    g. 1 600 000 - 1 999 999
    h. 2 000 000 og over
    i. Ønsker ikke oppgi
    j. Vet ikke
21. Hva er din høyeste fullførte utdanning?
    a. Grunnskole
    b. Videregående skole
    c. Høyskole/universitet – lavere grad (til og med 4 år)
    d. Høyskole/universitet – høyere grad (5 eller flere år)
    e. Ønsker ikke oppgi

-------*sidebrytning*-------

Takk for at du svarte på bakgrunnsspørsmålene!

Dersom du ønsker å være med i trekningen av to gavekort til en verdi av 1000 kr hver, kan du sende en SMS med kodeord «rosenborg» til 123456789 eller fylle inn e-postadressen din: _____

A.4. Trondheim II (English version)

Thank you for participating!

We wish to ask you a few background questions. This will help us understand how different demographic groups travel. Before you start using the app, we also ask that you read the information letter.

-------sidebrytning-------

Background questions

1. What is your gender?
    a. Male
    b. Female
    c. Prefer not to answer
2. What year were you born? _____
3. How did you receive information about this study?
    a. Letter by post
    b. Social media
    c. Leaflet in my mailbox
    d. Approached on the street/at the mall
    e. By phone call
    f. Other: _____

-------sidebrytning-------

4. How many people live in your household (including yourself)?
    a. 0—6 years: _____
    b. 7—10 years: _____
    c. 11—14 years: _____
    d. 15—17 years: _____
    e. 18—24 years: _____
    f. 25—45 years:_____
    g. 46—70 years: _____
    h. 70 years or older: _____
    i. Sum (calculated automatically)

-------sidebrytning------

5. Do you have more than one address of residence (e.g. as student or commuter)?
    a. Yes
    b. No
    c. Prefer not to answer
6. Do you have a driver's license for car?
    a. Yes
    b. No
    c. Prefer not to answer

-------sidebrytning-------

If 6 = a

7. Are you a member of a car-sharing scheme?
    a. Yes
    b. No
8. Are you a commercial driver?
    a. Yes
    b. No
    c. Don't know/prefer not to answer

-------sidebrytning-------

9. How many cars does your household have access to (including yourself)?
    e. Personal vehicle (petrol/diesel/hybrid): _____
    f. Personal vehicle (electric): _____
    g. Borrow car from family/friends/acquaintances: _____
    h. Company car: _____
    i. Other: _____
    j. Sum (automatically calculated): ___
10. Do you own or have access to?
    a. Bicycle, non-electric
    b. Bicycle, electric
    c. City bike (subscription by app or card)
    d. Moped/scooter
    e. Motorcycle
    f. Other (kickbike, skateboard or other)
    g. None of the above
11. What is your main occupation?
    a. Working full-time, paid
    b. Working part-time, paid
    c. Stay-at-home/homemaker
    d. Studying
    e. National/military/civilian service
    f. Parental leave
    g. Retired
    h. Unemployed
    i. Other: _____

-------sidebrytning-------

If 11 = a or b

12. What best describes the parking conditions at/close to your place of work?
    a. Free-of-charge, large capacity
    b. Free-of-charge, low capacity
    c. Pay-to-use, large capacity
    d. Pay-to-use, low capacity
    e. Don't know/not relevant
13. Are any of the following expenses (to/from work) covered by your employer?
    a. Vehicle expenses/company car
    b. Toll fees
    c. Parking (other than parking managed by your employer)
    d. Public transport
    e. Other
    f. None of the above
    g. Don't know/not relevant
14. In what sector do you work?
    a. Private sector
    b. Non-profit organizations
    c. Public sector (e.g. public administration, education, public health services)
    d. Other
    e. Prefer not to answer
15. Are your working hours regular, flexible, shift-based or other?
    a. Regular working hours, daytime
    b. Regular working hours, night-time
    c. Flexible working hours, daytime
    d. Shift work, rotation, night work etc.

e. I choose my own working hours
f. Other arrangements

16. Do you have a set meeting place at work (a place you meet at least 50 percent of your working days in the course of one year)?
    a. Yes
    b. Yes, I work from home
    c. No
    d. Don't know

-------*sidebrytning*-------

If 16 = c

17. What do you normally do on the workdays that you don't travel to/from work?
    a. Work from home
    b. Work from home and travel from home to meetings/clients/patients
    c. Leave straight from home to meetings/clients/patients
    d. Spend the night at/close to place of work
    e. Allocate full hours to fewer days

-------*sidebrytning*-------

18. How do you pay for public transport?
    a. Single ticket
    b. Period ticket (day, week, month or year)
    c. TT-card (subsidized taxi in case of disabilities)
    d. Don't know/other
19. Do you have access to parking near your place of residence?
    a. Yes, private parking
    b. Yes, zonal parking
    c. Yes, free street parking
    d. Yes, parking garage
    e. No
    f. Don't know/not relevant

-------*sidebrytning*-------

20. Could you please state your household's level of income (NOK before tax)?
    a. Below 200 000
    b. 200 000 - 399 999
    c. 400 000 - 599 999
    d. 600 000 - 799 999
    e. 800 000 - 999 999
    f. 1 000 000 - 1 599 999
    g. 1 600 000 - 1 999 999
    h. 2 000 000 and above
    i. Prefer not to answer
    j. Don't know
21. What is the highest level of education you have completed?
    a. Primary school
    b. Upper secondary school/high school
    c. Higher education/University – lower degree (up to 4 years)
    d. Higher education/University – higher degree (5 years or more)
    e. Prefer not to answer

-------*sidebrytning*-------

Thank you for answering the background questions!

If you want a chance to win one of two gift cards worth 1000 NOK please text "rosenborg" to 123456789 or fill in your e-mail address here: _____

A.5. Innherred

Takk for at du deltar!

Denne undersøkelsen vil gi oss et innblikk i reisevanene til folk på Innherred, og blir et viktig grunnlag for planlegging av attraktive steder og bærekraftig transport.

Vi starter med noen korte bakgrunnsspørsmål. Det tar ca. 5 minutter. Etterpå er det bare å reise som vanlig. Ta med telefonen og pass på at telefonen er oppladet når du er på farten. Takk for at du bidrar.

-----sidebrytning-----

Bakgrunnsspørsmål

1. Hvilket kjønn er du?
    a. Mann
    b. Kvinne
    c. Ønsker ikke oppgi

2. Hvilket år er du født? _____

3. Er du over 18 år?
    a. Ja
    b. Nei

Hvis 3=a -> [fortsett til 4]
Hvis 3=b -> Takk for at du ønsket å delta. Vi kan dessverre ikke samle data fra personer under 18 år og ber deg avinstallere TRavelVU.

4. Hvordan fikk du informasjon om undersøkelsen? Du kan velge mer enn ett alternativ (flersvar)
    a. Brev
    b. Brev i digital postkasse
    c. Via sosiale medier
    d. Kontaktet på gaten/kjøpesenter
    e. Via lokalavis
    f. Annet

-----sidebrytning-----

5. Hvor mange personer er dere i husholdningen (inkludert deg selv)? (Flersvar, oppgi i tall)
    a. 0-6 år: _____
    b. 7-10 år: _____
    c. 11-14 år: _____
    d. 15-17 år: _____
    e. 18-24 år: _____
    f. 25-45 år: _____
    g. 46-75 år: _____
    h. 75 år og eldre: _____

-----sidebrytning-----

6. Har du mer enn én bostedsadresse? (f.eks. som student eller pendler)
    a. Ja
    b. Nei

c. Ønsker ikke oppgi

7. Har du førerkort for bil?
    a. Ja
    b. Nei
    c. Ønsker ikke oppgi

-----sidebrytning-----

Hvis 7=a -> [fortsett til 8]
Hvis 7=b -> [fortsett til 9]

8. Er du yrkessjåfør?
    a. Ja
    b. Nei

9. Hvor mange biler har husholdningen tilgang til (inkludert deg selv)? Antall fordelt på type (Flersvar, oppgi i tall)
    a. Personbil (bensin): _____
    b. Personbil (diesel): _____
    c. Personbil (elektrisk): _____
    d. Personbil (hybrid): _____
    e. Andre : _____

10. Eier du eller disponerer du? (Flersvar)
    a. Vanlig sykkel, i brukbar stand
    b. El-sykkel
    c. By-sykkel (har app eller kort)
    d. Moped/scooter
    e. Motorsykkel (MC)
    f. Annet (spark, sparkesykkel, ståbrett eller lignende)
    g. Ingen av disse

-----sidebrytning-----

11. Hva regner du som din yrkesstatus eller ditt hovedgjøremål?
    a. Fulltidsjobb (inntektsgivende arbeid)
    b. Deltidsjobb (inntektsgivende arbeid=
    c. Hjemmeværende
    d. Student/elev
    e. Militærtjeneste/siviltjeneste
    f. Permisjon
    g. Pensjonist
    h. Arbeidsledig
    i. Annet

Hvis 11=a-b -> [fortsett til 12]
Hvis 11=c-i -> [fortsett til 18]

12. Hvilke parkeringsmuligheter er det på arbeidsstedet?
    a. Gratis, god kapasitet
    b. Gratis, begrenset kapasitet
    c. Betalt, god kapasitet
    d. Betalt, begrenset kapasitet
    e. Vet ikke/ikke relevant

13. Får du dekket noe av følgende utgifter til arbeidsreisen (til/fra jobb) av arbeidsgiver?
    a. Bilutgifter, firmabil
    b. Bompenger
    c. Parkering (på andre steder enn det arbeidsgiver disponerer)
    d. Kollektivtransport
    e. Annet
    f. Nei, ingen
    g. Vet ikke/ikke relevant

14. I hvilken sektor arbeider du?
    a. Privat næringsliv
    b. Organisasjonsliv (frivillige organisasjoner, stiftelser)
    c. Offentlig sektor (forvaltning, administrasjon, undervisning)
    d. Annet
    e. Ønsker ikke oppgi

15. Har du fast arbeidstid, fleksibel arbeidstid, skiftordning eller annet?
    a. Fast arbeidstid på dagtid
    b. Fast arbeidstid på natt
    c. Fleksibel arbeidstid på dagtid (fleksitid)
    d. Skift, turnus, nattarbeid mm.
    e. Kan jobbe når jeg vil
    f. Annen ordning

16. Har du fast oppmøtested på jobben? (Et oppmøtested man drar til minst 50 prosent av arbeidsdagene i løpet av et år)
    a. Ja
    b. Ja, jobber hjemmefra
    c. Nei
    d. Vet ikke

-----sidebrytning-----

Hvis 16=c -> [Fortsett til 17]
Hvis 16=a-b;d -> [Fortsett til 18]

17. Hva gjør du de arbeidsdagene du ikke reiser til/fra jobb?
    a. Arbeider hjemme
    b. Arbeider hjemme og drar derfra til evt. møter/kunder/pasienter e.l.
    c. Drar direkte hjemmefra til møter/kunder/pasienter e.l.
    d. Overnatter på/nær tjenestested/arbeidsplass
    a. Konsentrerer full arbeidstid på færre dager ordning

-----sidebrytning-----

18. Hvordan betaler du for kollektivreiser?
    a. Enkeltbillett
    b. Periodebillett (dag, uke, måned eller år)
    c. TT-kort
    d. Vet ikke/annet

19. Har du/dere egen parkeringsplass i nærheten av der du bor?
    a. Ja, privat parkering

b. Ja, soneparkering
c. Ja, gratis gateparkering
d. Ja, parkeringshus
e. Nei
f. Vet ikke/ikke relevant

-----sidebrytning-----

20. Hva er din høyeste fullførte utdanning?
    a. Grunnskole
    b. Videregående skole
    c. Høyskole/universitet – lavere grad (til og med 4 år)
    d. Høyskole/universitet – høyere grad (5 eller flere år)
    e. Ønsker ikke oppgi

21. Er det mulig for deg å oppgi husholdningens samlede årlige inntekt i et intervall (kr før skatt)?
    a. Under 200 000
    b. 200 000 - 399 999
    c. 400 000 - 599 999
    d. 600 000 - 799 999
    e. 800 000 - 999 999
    f. 1 000 000 – 1 599 999
    g. 1 600 000 – 1 999 999
    h. 2 000 000 og over
    i. Ønsker ikke oppgi
    j. Vet ikke

-----sidebrytning**-----**

Takk så langt!
Nå vil telefonen starte å logge dine reiser.
På slutten av dagen kan du sjekke hva TRavelVU har registrert og eventuelt korrigere for feilregistreringer. Hvis dagen er riktig registrert i TRavelVU bekrefter du at dagen er riktig. Det er bare dager som du aktivt bekrefter er riktige som vil inngå i undersøkelsen.

-----slutt-----

Appendix B. Interview guides

B.1. Focus groups

Introduksjon av intervjuer og retningslinjer for samtale

1. Oppmykningsspørsmål

1.1 Hvor lenge har dere studert?

1.2 Hvor ofte er dere på campus i løpet av en uke? Ca.

1.3 Hva er deres vanligste måte å reise på (en gjennomsnittlig dag)?

1.4 Hvor ofte har dere mobildata og GPS aktivert?

2. Egne erfaringer med intervju/spørreundersøkelser

2.1 Har dere deltatt på et intervju før (fokusgruppe eller enkeltintervju)? Hvorfor/hvorfor ikke?

2.2 Hvis ja, fullførte dere? Hvorfor/hvorfor ikke?

2.3 Tror dere en elektronisk deltakelse kan øke antall deltakere og gjennomførbarhet? / Har dere forslag til hvordan man kan få flere studenter til å bli med på undersøkelser?

2.4. Hva er maksgrensen for deltakelse? Lengde og tidspunkt.

4.1. Google Location History (GLH)

Introduksjon om hva Google Location History er, og vise på skjerm hvordan man kan aktivere den og hente informasjon om reisene side.

3.1 Har dere kjennskap med GLH fra tidligere? Hvor fikk dere informasjonen?

3.2 Hvilke tanker har dere rundt det å gi personlig GLH til forskning?

B.2. Personal Interviews

Intervjuguide intervju vår 2021: Mobilbruk og spørreundersøkelser

I: intervjuer leser opp

Introduksjon:

- Introduksjon av intervjuer og notatfører
- Om SmartRVU

I: *Jeg oppfordrer deg til å uttrykke ditt syn, erfaringer og følelser fritt og spontant og det er ingen rette eller gale svar. Resultatene blir brukt for å finne ut hva som motiverer til deltakelse og hvorvidt app egner seg i reisevaneundersøkelser.*

A: Bakgrunn

1. Alder
2. Arbeidssituasjon – ansatt, hjemmekontor, pensjonist o.l.
3. Hvor lenge har du eid en smarttelefon?
4. Hvor ofte har du mobildata og GPS aktivert?
5. Hvor ofte har du den med deg i lomme/veske (hjemme og ute)?

B: Spørreundersøkelser

1. Har du deltatt i en spørreundersøkelse før?
    a. Hvorfor/hvorfor ikke?
2. Hva er maksgrensen for deltakelse når det kommer til tidsbruk i en spørreundersøkelse (på telefon, web o.l.)?
3. Hva er viktig for om du deltar eller ikke?
    a. Tid (minutter)
    b. Lengde på undersøkelsen (fysisk)
    c. Tema
    d. Hvem som gjennomfører undersøkelsen (image, «name recognition»)
    e. Økonomisk incentiv
4. Er det andre ting som er viktig for om du deltar eller ei?

C: RVU

I: *Nå skal vi gå over til å snakke litt om reisevaneundersøkelser. Vi har både nasjonale og lokale reisevaneundersøkelser. De kartlegger hvordan folk beveger seg i hverdagen og samler bl.a. informasjon om hvor ofte man beveger seg mellom adresser, hvilket transportmiddel man bruker og hvor lang tid det tar å reise mellom disse. Vanligvis blir en stilt bakgrunnsspørsmål.*

1. Har du blitt kontaktet for å delta i en slik type RVU før?
    a. Deltok du?
    b. Hvis ja: hvordan opplevde du det?
    c. Hvis nei: hvorfor?

I: *Ny teknologi har åpnet for å bruke alternative datakilder som potensielt kan brukes som supplement eller erstatning til telefon- og webintervju. Jeg ønsker derfor å stille noen spørsmål om hva du tenker rundt bruk av denne typen alternativer*.

I: *En app vil kunne registrere reiser automatisk ved hjelp av GPS, bluetooth o.l. som er innebygd i telefonen slik at man ikke trenger rapportere enten på nett eller telefon. Et eksempel på dette er TravelVU..*

Presentasjon av TravelVu + forklaring av hvordan den brukes.

1. Hvilke tanker har du rundt det å gi denne typen informasjon til forskning?
2. Kunne du tenkt deg å delta i en slik undersøkelse?
    a. Hvorfor/hvorfor ikke?
        i. Hvis ja: hvor mange dager?

D: Registerdata

I*: Registerdata*[1] *er data som er hentet ut av et register, altså ikke data du produserer selv. Data fra ulike registre kan koples med hverandre for å finne svar på nye forskningsspørsmål. Registerdata kan kunne redusere svartiden eller til og med eliminere*

[1] Tall som ikke er samlet inn til andre formål enn statistikk. SSB bruker det mye.

behovet for spørreundersøkelser i visse tilfeller. For eksempel kan man hente informasjon fra folkeregisteret og kjøretøyregisteret istedenfor å spørre om adresse, bileierskap, alder osv.

1. Hvilke tanker har du rundt det å i større grad bruke dette i forskning?
    a. Har du noen tanker om bruk av dette i forskning?
    b. Hvilke tanker har du rundt det å bruke dette for å erstatte spørsmål i spørreundersøkelser?

E: Avslutningsspørsmål

1. Det er mer og mer vanskelig å få folk til å delta i spørreundersøkelser, inkludert reisevaneundersøkelser. Har du forslag til hvordan man kan få flere til å delta?
2. Hva er den ideelle spørreundersøkelsen?
    a. Tid
    b. Gaver/insentiv
    c. Telefon, web, app
3. Har du andre tanker rundt det å bruke GPS og bluetooth (og registerdata) i forskning?

Appendix C. Invitation letters

C.1. Trondheim I

NTNU

NORDMANN, OLA
TRONDHEIMSVEIEN 1
7000 TRONDHEIM

Invitasjon til deltakelse i reisevaneundersøkelse med app

Bli med i forskningsprosjektet SmartRVU! Bidra til utviklingen av transporttilbudet og kanskje er du en av de heldige som vinner **10 Flax-lodd.**

Vi inviterer deg til å bli med på et spennende forskningsprosjekt i regi av NTNU, hvor vi tester ut bruk av mobilapp til innsamling av reisevanedata. For at planleggere og beslutningstakere skal få kunnskap om hvordan transportsystemet blir benyttet, trengs det data. Tidligere ble denne typen data samlet inn gjennom tidkrevende telefonintervju. Folk flest har en smarttelefon som de alltid bærer med seg, og det gir muligheter til å samle data mye mer elegant.

Et hovedmål med å teste nye metoder er at de som deltar i undersøkelsen skal bruke minst mulig tid på dette, og vi forventer at innsatsen til deltagerne totalt skal ligge på 10-15 minutter over 1-2 uker.

Hvis du velger å delta i undersøkelsen, innebærer det at du fyller ut et spørreskjema med bakgrunnsspørsmål på telefonen og bruker applikasjonen TRavelVU i 7-14 dager innen 12. juni.

Det er selvsagt frivillig å delta, men vi vil gjerne ha DEG med.

Det skjer mange prosjekter i Trondheimsområdet nå, og din innsats kan være med å sette preg på planleggingen av transportsystemet framover.

Last ned app'en ved å søke på «TRavelVU» i Google Play eller App Store og velge undersøkelsen «Nidaros». Du kan også laste ned appen ved å bruke QR-koden nedenfor.

Vinnerne av lotteriet trekkes den 20. juni og disse blir kontaktet via e-post. Mer informasjon om prosjektet finner du her:
www.ntnu.no/smartrvu

Med vennlig hilsen
Gunnhild Svaboe
Doktorgradsstipendiat
Institutt for bygg- og miljøteknikk, NTNU

SmartRVU Jernbane-direktoratet AVINOR KYSTVERKET NyeVeier Statens vegvesen

C.2. Trondheim II

NTNU

«navn»
«adresse»
«postnummer» «poststed»

Invitasjon til å bli med på reisevaneundersøkelse med app

Bli med og påvirk trafikkløsninger i Trondheim! NTNU inviterer deg til å bli med på en undersøkelse om dine transportvaner. Informasjonen som samles inn brukes for å få en bedre forståelse av hvordan mennesker reiser og hvordan transportsystemet i Trondheim bør planlegges for å møte dine behov. Det eneste du trenger for å delta er en smarttelefon.

Hvorfor bli med?

Det skjer mye med kollektivtilbudet i Trondheim nå. Uansett om du ferdes mye eller lite ute i trafikken til daglig, er alle bidrag viktige for å kunne planlegge et best mulig transporttilbud, til fordel for deg og alle andre.

Hva innebærer det å delta?

Deltakelse innebærer at du bruker appen TravelVu minst 1 dag, gjerne flere, innen **11. november**. Appen samler inn informasjon om reisene dine automatisk så lenge du har telefonen med deg. Det eneste du derfor trenger å gjøre er å godkjenne, og eventuelt korrigere, reiser og dager. Kun godkjente dager inngår i undersøkelsen.

Hvordan bli med?

1. Last ned appen TravelVu fra **App Store** eller **Google Play** eller bruk QR-koden
2. Åpne appen og velg undersøkelsen som heter **Trondheim**
3. Følg instruksjonene i appen

Nå er du klar! Når du har bekreftet minst en dag, er din deltakelse registrert. Mer informasjon om studien finner du på vår nettside: **www.ntnu.no/smartrvu/rvu**

Med vennlig hilsen

Gunnhild B. A. Svaboe
Doktorgradsstipendiat
Institutt for bygg- og miljøteknikk (IBM), NTNU
e-post: smartrvu@ibm.ntnu.no

Vinn gavekort!
Alle som godkjenner minst én dag kan være med i trekningen av to gavekort verdt 1000 kr!

SmartRVU · Jernbane-direktoratet · TravelVu · Statens vegvesen

Appendix D. Information letters

D.1. Focus groups

Forespørsel om deltakelse i forskningsprosjektet

"Smart RVU - Pilot"

Bakgrunn og formål

Formålet med studien er (1) å samle informasjon om studenters erfaringer med spørreundersøkelser og intervjuer og (2) mulige måter å øke deltakelsen på undersøkelser om reisevaner.

Gruppeintervjuet er et pilotprosjekt innenfor fagområdet «Smart RVU» i samarbeid med NTNU og Vegvesenet.

Utvalget er studenter ved NTNU som har studert minst 1 semester, og rekrutteringen skjer via personlige nettverk.

Hva innebærer deltakelse i studien?

Deltakelse i studien innebærer deltakelse på et gruppeintervju sammen med andre studenter som varer i ca. 1-2 timer. Spørsmålene vil omhandle erfaringer med spørreundersøkelser og intervju via telefon, epost, digitalt o.l. og diskusjon/tilbakemeldinger på alternative måter å samle inn data om reisevaner. Dataene vil registreres gjennom bruk av lydopptak av gruppesamtalen.

Hva skjer med informasjonen om deg?

Alle personopplysninger vil bli behandlet konfidensielt. Kun intervjuer, moderator/observerer og prosjektleder vil ha tilgang til personopplysninger/opptak, og opptakene vil lagres på en privat datamaskin der alle deltakerne vil anonymiseres ved å ikke bruke ekte navn. Navneliste vil være atskilt fra øvrige data. Deltakerne vil ikke kunne gjenkjennes i publikasjonen.

Prosjektet skal etter planen avsluttes innen 30.11.2018 og da vil alle personopplysninger og opptak destrueres.

Frivillig deltakelse

Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Dersom du trekker deg, vil alle opplysninger om deg bli anonymisert.
Dersom du ønsker å delta eller har spørsmål til studien, ta kontakt med Gunnhild Svaboe på telefon eller epost (gunnhild.svaboe@ntnu.no, 48191728).

Studien er meldt til Personvernombudet for forskning, NSD – Norsk senter for forskningsdata AS.

Samtykke til deltakelse i studien

Jeg har mottatt informasjon om studien, og er villig til å delta

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(Signert av prosjektdeltaker, dato)

D.2. Personal interviews

Informasjon om forskningsprosjektet SmartRVU

I dette skrivet gir vi deg informasjon om målene for dette forskningsprosjektet og hva prosjektet innebærer for deg.

Formål

Dette er en forespørsel om deltakelse i forskningsprosjektet «SmartRVU». Formålet med intervjuene er å samle informasjon om erfaringer med spørreundersøkelser og å få en bedre forståelse for motivasjon til deltakelse i reisevaneundersøkelser. Intervjuene er en del av en doktorgradsstudie.

Hvem er ansvarlig for forskningsprosjektet?

Institutt for bygg- og miljøteknikk (IBM) ved Norges teknisk-naturvitenskapelige universitet (NTNU) er ansvarlig for prosjektet.

Hva innebærer prosjektet for deg?

Deltakelse innebærer å være med på et intervju som varer mellom 30 minutter og 1 time. Det vil noteres under intervju.

Det er frivillig
Du kan når som helst protestere mot at du inkluderes i dette forskningsprosjektet, du trenger ikke å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Kun personer ansatt ved NTNU tilknyttet forskningsprosjektet SmartRVU vil ha tilgang til datamaterialet.
- Navnet og kontaktopplysningene dine vil jeg erstatte med et pseudonym som lagres på egen navneliste adskilt fra øvrige data.

Det vil ikke være mulig å gjenkjenne deg i publikasjoner og du vil tildeles et pseudonym.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 31.10.2022. Da vil navn og kontaktinformasjon slettes.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg fordi forskningsprosjektet er vurdert å være i allmennhetens interesse, men du har anledning til å protestere eller trekke deg dersom du ikke ønsker å delta i prosjektet.

På oppdrag fra Institutt for bygg- og miljøteknikk (IBM) ved Norges teknisk-naturvitenskapelige universitet (NTNU) har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- å protestere
- innsyn i hvilke personopplysninger som er registrert om deg
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hvis du har spørsmål til studien, eller ønsker å vite mer eller å benytte deg av dine rettigheter, ta kontakt med:

- Institutt for bygg- og miljøteknikk, NTNU ved Gunnhild B. A. Svaboe, på epost (gunnhild.svaboe@ntnu.no).
- Vårt personvernombud: Thomas Helgesen på epost (thomas.helgesen@ntnu.no)

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Gunnhild Svaboe

(Stipendiat)

D.3. Student pilot

Forespørsel om deltakelse i forskningsprosjektet «Smart RVU – TRavelVU»

Bakgrunn og formål
Undersøkelsen skal kartlegge de overordnede transportvanene blant studenter i Trondheim, og å teste hvordan man kan samle inn reisevanedata gjennom bruk av applikasjoner. Uansett om du ferdes mye eller lite ute i trafikken til daglig er det viktig at du deltar, slik at undersøkelsens resultater blir korrekte. Formålet er å utvikle bedre metoder for å samle inn reisevanedata, slik at transportsystemet og transporttilbudet kan planlegges best mulig for fremtiden, til fordel for deg og alle andre. Undersøkelsen gjennomføres av NTNU i samarbeid med Statens vegvesen, Trondheim kommune og Trivector.

Hva innebærer deltakelse i studien?
Deltakelse i studien innebærer å laste ned applikasjonen TRavelVU på mobil, fylle inn bakgrunnsinformasjon i applikasjonen og registrere formål med reisen og transportmiddel. Dataene vil registreres passivt via applikasjonen, dvs. reisene registreres basert på GPS, akselerometer og WiFiteknologi. Det blir blant annet samlet inn data om hvor du reiser til og
fra, når på døgnet, samt hvilke transportmidler du bruker, ved at det blir samlet inn koordinater via applikasjonen. Deltakelsen varer i 7 dager og tidsbruk totalt er 5-10 minutter. Det tar omtrent 2 minutter å fylle inn bakgrunnsinformasjon og 30 sekunder til 1 minutt å verifisere reiser per dag, avhengig om du verifiserer kontinuerlig (anbefales) eller ei.

Hva skjer med informasjonen om deg?
Alle personopplysninger vil bli behandlet konfidensielt og vil bli slettet ved prosjektets slutt.
Kun prosjektgruppen vil ha tilgang til datamaterialet. Stipendiat Ray Pritchard og masterstudent Ingrid Runestad skal benytte datamaterialet i sine respektive prosjekter. Den tekniske gjennomføringen av spørreskjemaundersøkelsen foretas av Gunnhild Svaboe og Trude Tørset/NTNU. Forsker får utlevert data fra Trivector uten tilknytning til e-post/IPadresse/telefonnummer, og all kommunikasjon mellom applikasjon og server krypteres. Datamaterialet vil lagres på passordbeskyttet privat datamaskin. Kun prosjektgruppen vil ha tilgang til adresser. Prosjektet skal etter planen avsluttes innen 30.11.2018 og da vil alle personopplysninger destrueres.

Frivillig deltakelse
Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Du kan be Institutt for bygg- og miljøteknikk (NTNU) om å slette disse dataene. Ved å laste ned applikasjonen samtykker du til deltakelse. Dersom du har spørsmål til studien, ta kontakt med Gunnhild Svaboe på telefon eller epost (smartrvu@ibm.ntnu.no, 48191728). Studien er meldt til Personvernombudet for forskning, NSD – Norsk senter for forskningsdata AS.

D.4. Trondheim I

Forespørsel om deltakelse i RVU Trondheim og omegn

Undersøkelsen skal kartlegge transportvanene blant personer i Trondheim og omegn. Uansett om du ferdes mye eller lite ute i trafikken til daglig er det viktig at du deltar, slik at transporttilbudet kan planlegges best mulig for fremtiden, til fordel for deg og alle andre. Formålet er å samle inn informasjon om hvordan folk bosatt i Trondheim og omegn reiser, og evaluere hvorvidt en app egner seg for å samle inn reisevanedata. Gode reisevanedata er viktig for å kunne utvikle et bedre transporttilbud. Hvis du velger å delta i undersøkelsen, innebærer det at du fyller ut et spørreskjema med bakgrunnsspørsmål og bruker applikasjonen TRavelVU i 7-14 dager. Kun bekreftede dager blir analysert. TRavelVU samler inn informasjon om:

- Reisemiddel
- Distanse og hastighet
- Varighet
- Geografisk plassering
- Formål med reisen/aktivitet

Reisemiddel vil si hvordan du reiste (bilfører, buss, sykkel, gange, taxi osv.). Distanse og hastighet innebærer hvor langt du reiste (km og m) og hvor raskt (km/t) du da beveget deg mellom to steder. Varighet vil si hvor lang tid du brukte på en reise og hvor lenge en aktivitet varte. Geografisk plassering vil si hvor du dro fra, hvor du reiste og ruten du valgte for å komme deg dit. TRavelVU estimerer reisemiddel, distanse og hastighet, varighet og geografisk plassering automatisk basert på GPS, WiFi/mobildata og akselerometer (akselerasjonsmåler). Dette er grunnen til at appen ber om tilgang til disse tjenestene og at de må være på under hele deltakelsen. Strømsparemodus må også være avslått for at appen skal fungere best mulig. Formålet med reisen (hva du gjorde) definerer du selv ved å velge mellom kategorier i appen (hjemme, arbeid, skole/utdanning, hobby, innkjøp osv.).

Reisedata og svar på spørreskjema kan undersøkes og endres i TRavelVU-appen. Dersom den automatiske registreringen ikke er korrekt kan du selv endre reisemiddel, slå sammen og dele opp reiser og aktiviteter. Du har også mulighet til å slette reiser og aktiviteter. Vi anbefaler at du starter å registrere reiser, gjøre eventuelle revideringer og bekrefte dager tidlig (første kveld eller andre dag).

Frivillig å delta

Det er frivillig å delta i prosjektet. Alle opplysninger om deg blir behandlet konfidensielt og i samsvar med personvernregelverket. Kun autoriserte personer har tilgang til dataene. Når resultatene presenteres vil det være umulig å identifisere individer. Dette prosjektet er en

doktorgradsstudie som etter planen avsluttes 01.11.2021. Da vil alle personopplysninger slettes. Institutt for bygg- og miljøteknikk ved NTNU er ansvarlig for prosjektet. NTNU samarbeider med Trivector Traffic AB.

Da vi samler inn GPS-spor har vi strenge regler for hvem som kan håndtere data og hvordan. Vi gjør mest mulig for at du skal være anonym når du deltar. Appen interagerer ikke med andre apper på telefonen, og det skjer en kryptering mellom telefon og server.

Dersom du deltar i lotteri: e-post vil lagres separat fra øvrig datamateriale når det hentes ut. Den vil bli slettet når lotteriet er over.

Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi grunn. Alle opplysninger vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg,
- å få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Vi behandler opplysninger om deg basert på ditt samtykke. Opplysningene behandles konfidensielt og i samsvar med personregelverket. Dersom du ønsker at data skal slettes må du oppgi din TRavelVU-ID til Trivector Traffic AB eller NTNU. TRavelVU-ID er ID-nummeret din telefon har fått av TRavelVU (du kan finne dette under «innstillinger» i hovedmenyen).

Ved å bekrefte dager i appen godkjenner du at NTNU og Trivector Traffic AB behandler personopplysninger om deg i enighet/samsvar med det som er beskrevet.

Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Norges teknisk-naturvitenskapelige universitet ved Gunnhild B. A. Svaboe, på e-post (smartrvu@ibm.ntnu.no) eller telefon: 48 19 17 28.
- Vårt personvernombud: Thomas Helgesen på e-post (thomas.helgesen@ntnu.no)
- NSD – Norsk senter for forskningsdata AS, på e-post (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

D.5. Trondheim II

Deltakelse i RVU Trondheim

Undersøkelsen skal kartlegge transportvanene blant personer i Trondheim og omegn. Uansett om du ferdes mye eller lite ute i trafikken til daglig er det viktig at du deltar, slik at transporttilbudet kan planlegges best mulig for fremtiden, til fordel for deg og alle andre. Formålet er å samle inn informasjon om hvordan folk bosatt i Trondheim og omegn reiser, og evaluere hvorvidt en app egner seg for å samle inn reisevanedata. Gode reisevanedata er viktig for å kunne utvikle et bedre transporttilbud. Hvis du velger å delta i undersøkelsen, innebærer det at du fyller ut et spørreskjema med bakgrunnsspørsmål og bruker applikasjonen TravelVu i minst 1 dag. Kun bekreftede dager blir analysert. TravelVu samler inn informasjon om:

- Reisemiddel
- Distanse og hastighet
- Varighet
- Geografisk plassering
- Formål med reisen/aktivitet

Reisemiddel vil si hvordan du reiste (bilfører, buss, sykkel, gange, taxi osv.). Distanse og hastighet innebærer hvor langt du reiste (km og m) og hvor raskt (km/t) du da beveget deg mellom to steder. Varighet vil si hvor lang tid du brukte på en reise og hvor lenge en aktivitet varte. Geografisk plassering vil si hvor du dro fra, hvor du reiste og ruten du valgte for å komme deg dit. TravelVu estimerer reisemiddel, distanse og hastighet, varighet og geografisk plassering automatisk basert på GPS, WiFi/mobildata og akselerometer (akselerasjonsmåler). Dette er grunnen til at appen ber om tilgang til disse tjenestene og at de må være på under hele deltakelsen. Strømsparemodus må også være avslått for at appen skal fungere best mulig. Formålet med reisen (hva du gjorde) definerer du selv ved å velge mellom kategorier i appen (hjemme, arbeid, skole/utdanning, hobby, innkjøp osv.).

Reisedata og svar på spørreskjema kan undersøkes og endres i TravelVu-appen. Dersom den automatiske registreringen ikke er korrekt kan du selv endre reisemiddel, slå sammen og dele opp reiser og aktiviteter. Du har også mulighet til å slette reiser og aktiviteter. Vi anbefaler at du starter å registrere reiser, gjøre eventuelle revideringer og bekrefte dager tidlig (første kveld eller andre dag).

Frivillig å delta

Det er frivillig å delta i prosjektet. Alle opplysninger om deg blir behandlet konfidensielt og i samsvar med personvernregelverket. Kun autoriserte personer har tilgang til dataene. Når resultatene presenteres vil det være umulig å identifisere individer. Dette prosjektet er en doktorgradsstudie som etter planen avsluttes 01.11.2021. Da vil alle personopplysninger slettes. Institutt for bygg- og miljøteknikk ved NTNU er ansvarlig for prosjektet. NTNU samarbeider med Trivector Traffic AB.

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- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Vi behandler opplysninger om deg basert på ditt samtykke. Opplysningene behandles konfidensielt og i samsvar med personregelverket. Dersom du ønsker at data skal slettes må du oppgi din TravelVu-ID til Trivector Traffic AB eller NTNU. TravelVu-ID er ID-nummeret din telefon har fått av TravelVu (du kan finne dette under «innstillinger» i hovedmenyen).

Ved å bekrefte dager i appen godkjenner du at NTNU og Trivector Traffic AB behandler personopplysninger om deg i enighet/samsvar med det som er beskrevet.

Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

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- NSD – Norsk senter for forskningsdata AS, på e-post (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Appendix E. Recruitment material

E.1. SMS reminder text - Trondheim I

Hei! Vi minner om invitasjonen til undersøkelse om reisevaner i Trondheim med app. Klikk her for å bli med/mer info: www.ntnu.no/smartrvu/nidaros. Mvh NTNU

E.2. SMS reminder text - Trondheim II

Hei! Vi minner om invitasjon til undersøkelse om reisevaner i Trondheim med app. Klikk her for å bli med/lære mer: www.ntnu.no/smartrvu/rvu. Vennlig hilsen NTNU

E.3. Advertisement at adressa.no (Trondheim I)

Appendix F. German Mobility Panel (MOP)

F.1. Documents used

Table F.1. Documents used in the analysis of MOP

Phase 1	Phase 2
(Karlsruhe Institute of Technology, no date) (Ecke, Chlond, Magdolen, Hilgert, *et al.*, 2020) (Ecke, Chlond, Magdolen and Vortisch, 2020)	(Eisenmann *et al.*, 2018) (Chlond *et al.*, 2015)

F.2. Results

The first MOP data collection was done in 1994 and has since been conducted yearly. It is funded by the German Federal Ministry for Digital and Transport, KANTAR is responsible for the fieldwork (recruitment and data collection), and the Institute of Transport Studies of the Karlsruhe Institute of Technology (KIT) is responsible for the design and scientific supervision (Karlsruhe Institute of Technology, no date; Eisenmann *et al.*, 2018). MOP collects information about everyday mobility, car mileage and fuel consumption.

MOP is a longitudinal national household panel travel survey, i.e. it collects information about multiple days and multiple periods for each respondent (Karlsruhe Institute of Technology, no date; Eisenmann *et al.*, 2018). Respondents are asked to participate for three years (rotating sample). Each year, a subset of the households in the samples are removed, either due to 1) withdrawal or 2) they are replaced with a new household when they have participated in three consecutive waves.

The survey design of MOP has changed little to ensure comparability. In summary, all members of the household 10 years or older fill in a trip diary for one week during autumn, and every spring they are asked to fill in a 'mileage diary' for a 8 week period (Karlsruhe Institute of Technology, no date; Chlond *et al.*, 2015). Respondents are also asked to report their car mileage at the beginning and end of their response period.

Due to declining participation, changing legal conditions and the emergence of new survey methods, some survey design changes were implemented in 2013 (Chlond *et al.*, 2015). A multi-mode survey solution was implemented due to certain socio-demographic groups being under-represented in the data set and declining response rates. Further, traditionally, the sample was chosen by random digit dialling (RDD) landline phone numbers. In 2013, an additional sample of mobile phone users was added. The argument is that using RDD and a sample of mobile phone users makes it possible to reach both mobile- *and* landline-only households (Chlond *et al.*, 2015). The third major change is that the sample was increased to 1500 households. According to Chlond *et al.* (2015), the change in sampling has caused a change in the observed mobility.

Table F.2. German Mobility Panel (1994-2019)

Year	Method	Sampling	Interviews	Response rate	Trips	Immobile respondents	Structural changes
1994	Contacted by the telephone. PAPI for travel diary administration	10+ years RDD	N/A	N/A	N/A	N/A	First MOP
2008	Contacted by the telephone. PAPI for travel diary administration	10+ years RDD	N/A	N/A	3.4	8.4 %	
2013	CAWI and PAPI (optional)	10 + years Samples drawn from landlines and mobile phones	N/A	N/A	3.4	7.6 %	Multi-mode administration, added mobile phone sample, increased sample size
2019	CAWI and PAPI (optional)	10 + years Samples drawn from landlines and mobile phones	N/A	N/A	3.2	11 %	

F.3. Bibliography

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